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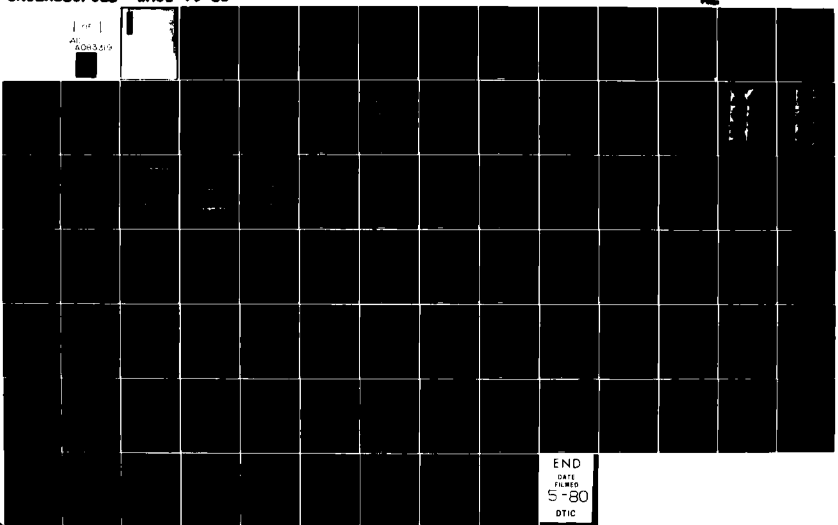

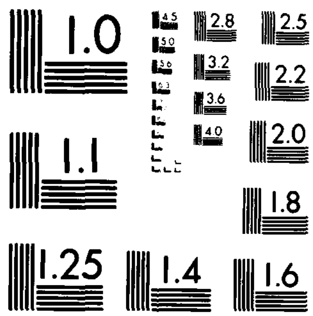

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

We describe the current-meter data collected from 4 moorings (11 current meters) in the vicinity of the Blake-Bahama Outer Ridge. These 12-month records document both mean and eddy activity of the deep western boundary current of the North Atlantic, near 30°N. In addition, the temperature records show large-scale, westward propagating eddies in which the ocean above the thermocline actively affects the abyssal jet.

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The Deep Western Boundary Current at the Blake-Bahama Outer Ridge: Current Meter and Temperature Observations, 1977-78

by

Carol A. Mills
Peter Rhines

Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

December 1979

Technical Report

Prepared for the National Science Foundation under Grants OCE-76-81190, and for the Office of Naval Research under Contract N000-14-76-C-0197; NR-083-400. Reproduction in whole or in part is permitted for any purpose of the United States Government. This report should be cited as: Woods Hole Oceanographic Institution Technical Report WHOI-79-85.

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Valentine Worthington

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Abstract

We describe the current-meter data collected from 4 moorings (11 current meters) in the vicinity of the Blake-Bahama Outer Ridge. These 12-month records document both mean and eddy activity of the deep western boundary current of the North Atlantic, near 30°N. In addition the temperature records show large-scale, westward propagating eddies in which the ocean above the thermocline actively affects the abyssal jet.

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PREFACE

This volume is the twenty-first in a series of Data Reports presenting moored current meter and associated data collected by the W.H.O.I. Buoy Group.

Volumes I through XX present data from the years 1963-1971, and from several special experiments: the 1970 Pollard array, the 1973 IWEX array, the 1973 MODE array, the MODE Site moorings, the 1974 Rise array, the Saint Croix mooring measurements, the POLYMODE Array II experiment, the POLYMODE Array I experiment, and the 1978 JASIN Experiment.

Volume XXI presents the Western Boundary Undercurrent Experiment.

Volume Number	WHOI Ref. #	Authors	Year, Experiments Notes
I	65-44	Webster, F., and N. P. Fofonoff	
II	66-60	Webster, F., and N. P. Fofonoff	
III	67-66	Webster, F., and N. P. Fofonoff	
IV	70-40	Pollard R. T.	1965 Measurements
V	71-50	Tarbell, S. and F. Webster	1966 Measurements
VI	74-4	Tarbell, S.	1967 Measurements
VII	74-52	Chausse, D. and S. Tarbell	1968 Measurements
VIII	75-7	Pollard, R. T. and S. Tarbell	1970 Measurements
IX	75-68	Tarbell, S., M.G. Briscoe and D. Chausse	1973 IWEX Array
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XII	76-101	Chausse, D. and S. Tarbell	1973 MODE Array
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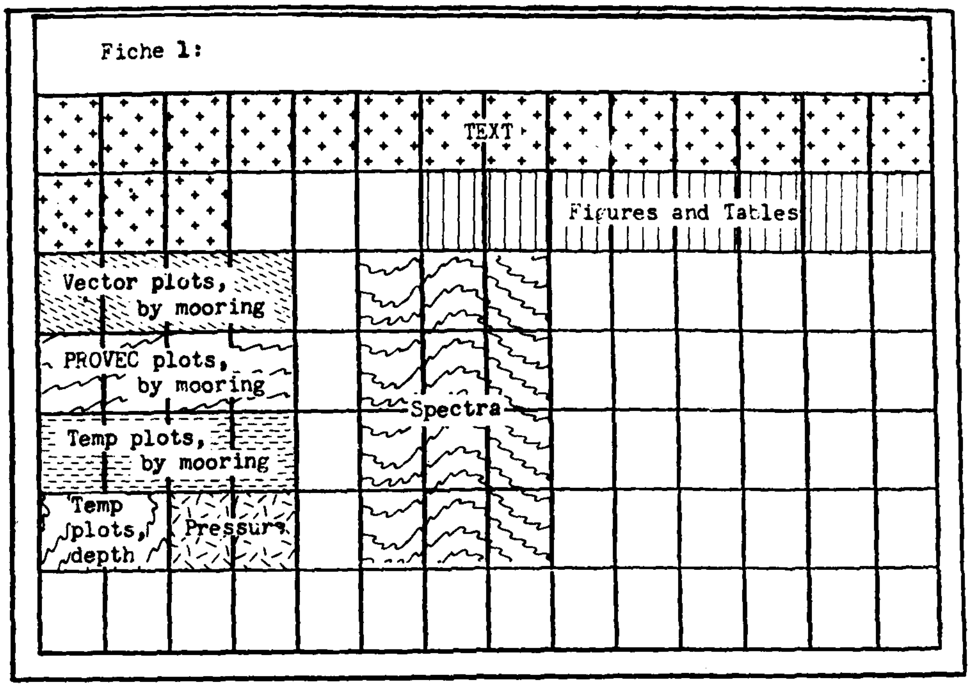
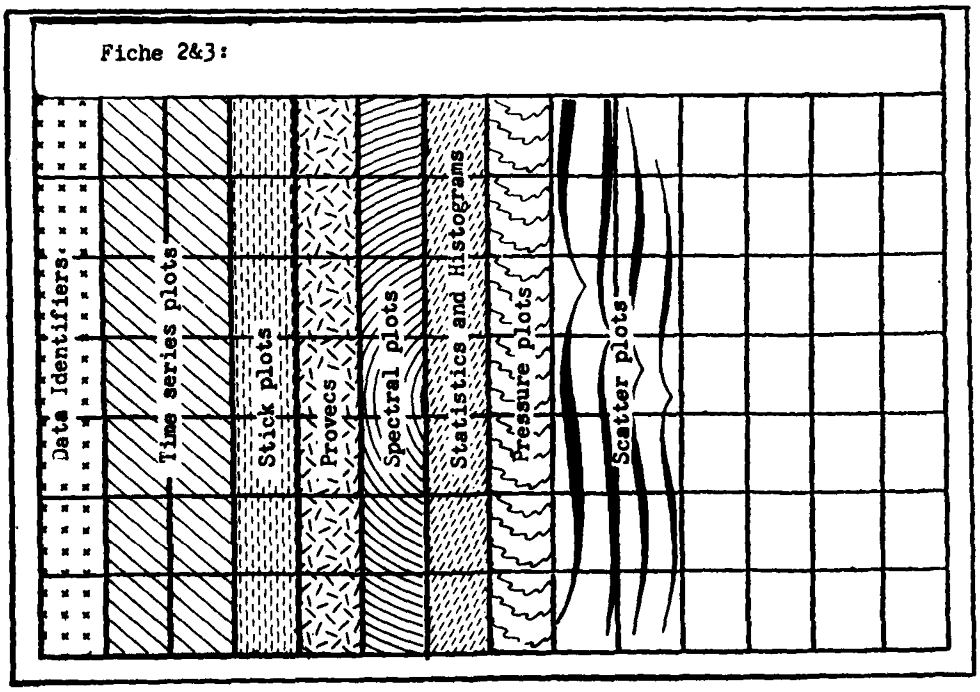
XX	79-56	Spencer, A.	1974-1975 Rise Array

Microfiche Index

The Microfiche Index in this document may be obtained from: Woods Hole Oceanographic Institution, ATTN: Document Library, Woods Hole, MA 02543

Diagram of fiche layout





EXPERIMENT DESCRIPTION

In May 1977, the Moored Array Group set out 5 moorings with 15 temperature recording VACM current meters and 2 M.I.T. temperature-pressure (TP) recorders in the vicinity of the Blake-Bahama Outer Ridge (near 30.5°-31°N, 73.5°-76.5°W, see figure 1). The duration of the observations was twelve months. The purpose was to provide the first long-term measurements of the deep western boundary current in the North Atlantic, sometimes known as the Western Boundary Undercurrent. Supporting hydrographic, geo-chemical, radio-chemical, and XBT data were collected by Rhines on cruise 31 of R/V Oceanus, and during the mooring pick-up, cruise 100 of R/V Atlantis II. At the deployment, cruise 66 of R/V Knorr, hydrographic data were collected by Larry Armi.

The 12-month mean currents, figure 4, show the abyssal flow, with speed increasing downwards (below the thermocline). The deepest measurements (200 m above bottom) lie close to topographic contours. The bottom slopes steeply in this area. The mean path of the abyssal current thus follows the deep topographic boundary on its way south.

As one moves upward from the bottom, however, the mean currents veer significantly. This veering is always in a sense appropriate to allow some of the flow tc rise up and over the topographic obstacles. At mooring 618 for example, the flow has passed southwestward along the gentle continental rise north of 32°N. Then, it is confronted with a major obstacle, the Blake-Bahama Outer Ridge, which forces it to turn southeastward. The convergence of the isobaths suggests a thinning and acceleration of the flow.

The current only partially negotiates this turn, flowing up and over the Ridge crest at shallower levels. Even in ignorance of the topography, we would know that clockwise veering as one moves upward requires upward vertical velocity, from Bryden's (1976) rewriting of the thermal wind equation. The vertical velocity inferred in this way from the veering is indicated in figure 4.

The mean current in the deep jet reaches 21 cm sec^{-1} at 3800 m, on the eastern flank of the Ridge (record 6183, figure 6) decreasing upward to 5 cm sec^{-1} at 2000 m (often taken to be the 'level of no motion' in classical studies). Combined with the hydrography (e.g. the August 1977 section of Oceanus 31, figure 2) we can provide estimates of the volume transport of the abyssal circulation.

The time-series from the deep jet, page 18, show the mean flow standing out well above the eddies. The jet reaches speeds of 40 cm sec^{-1} and, occasionally, shuts off entirely.

Eastward of the jet core, we placed mooring 620 to catch the seaward fringe of the current. In fact, the 12-month mean velocity at this point was north-westward at all levels (figure 4). Comparing with figure 2, we see that the broad region of sloping isotherms, which would suggest a broad southward flow, is atypical. The instantaneous current (page 19) was southward (i.e., atypical) during this section, and during several others that we have taken. (The important section of Amos, Gordon and Schneider (1971) also resembled this one.) This underlines the value of long-term current measurements in augmenting hydrographic determinations of transport. The mean southward current is thus more barotropic and more narrowly confined (laterally) than the classical, purely hydrographic, determinations suggested. One of a number of chemical tracer sections from Oceanus-31 is shown in figure 3. This shows the (bomb-test)tritium concentration, forming a strong, narrow core in the abyssal jet (Jenkins and Rhines, 1979).

On the west side of the Ridge, mooring 617, the mean flow involves a downward vertical velocity, complementary to mooring 618. Otherwise, the flow is basically along depth contours. Downstream, at mooring 616 the jet once again encounters a converging, leftward bend in the isobaths, and the vertical velocity is positive, with the upper levels negotiating the turn less perfectly than the deep layers.

The deep flow at the seaward end of the array, mooring 620, is oscillatory with roughly 6 month period. This is clearly a different new regime, from that of the jet. The northwestward mean is consistent with the schematic circulation diagram of Worthington (1976), which has a strong, deep gyre beneath and south of the Gulf Stream, flowing northwestward in this area.

The single upper-level current meter, 6171, at 600 m, shows a 'parade' of warm and cold eddies passing westward across the region (page 25 and page 17). Some of the cold eddies are well documented as Gulf Stream rings by Richardson (1969). These alternate with larger warm features in which the 18° water content is particularly great.

The upper-level mean flow at 6171 is strongly westward, in nearly the same direction as the isobaths and the deep flow. This may represent a concentrated inflow to the Florida Current, which is known to entrain considerable amounts of water between the Florida Straits and Cape Hatteras.

The temperature time-series show unexpected coherence in both horizontal and vertical. Despite the 0(100 km) spacing of the moorings one sees in page 28 a systematic westward phase motion of temperature features, across the array at 2000 m, at speeds of order 3 km day^{-1}. The hydrographic sections verify that very large-scale warm eddies (of order 300 km in east-west extent) were present, accounting for this coherence. In this special region, where the southward flowing boundary current turns westward, its path temporarily coincides with the sense of westward propagation that prevails on a β-plane.

The vertical interrelationships of temperature show coherence between 600 m and 2000 m, page 25, and coherence of certain events between these levels and the deeper water, pages 24, 25, 26. The most striking effect is the penetration of 'sudden warmings' down through the water column, e.g. at the end of July at mooring 618. This occurs at the leading front of large, warm eddies of 18' water, as it passes westward across the moorings. This deepening of the thermocline evidently imposes downward vertical velocity right to the sea floor (The downward motion is made possible by the steep slope of the ridge.)

The corresponding velocity events, page 18, current meter 6183, show the deep jet to switch off suddenly during the warm pulse. It is uncertain whether this represents a seaward meander or a pulse-like event in which the jet ceases over the entire cross-section. In either case, it demonstrates how eddies above the thermocline can induce major disruptions in the deep flow. After this 'shock' the deep jet quickly recovers, surging to a speed of 40 cm sec^{-1}, the fastest of the entire year.

Final resolution of the coherent structure of the jet pulsations will, regrettably, not be possible from this data set; mooring 619, which was set 16 km northeast of mooring 618 to provide such information, was silent during attempts to transpond with it in August 1977 and again in May 1978.

It is speculated that the height, stiffness, and drag of the mooring (bottom to 600 m depth, with 70 glass balls) led it to drag southeastward in the unexpectedly strong currents. Acoustic searches were carried out, extending 10 miles upstream (NW), 40 miles downstream (SE) and back, on the May 1978 pick-up cruise, R/V Atlantis-II-100.

Instrumentation

The instruments represented in this data report are the Vector Averaging Current Meter (VACM) and a temperature and pressure recording device (T/P) developed at M.I.T. (Wunsch and Dahlen, 1974). The VACM uses a Savonius rotor to measure water speed and a vane and internal compass to measure direction. East and North components are calculated from the compass and vane values 8 times per rotor revolution. The components are accumulated over the recording interval resulting in vector averaged velocities.

The VACM has a thermistor embedded in its end cap just above the vane. Temperature accuracy is approximately .01°C (Payne et al., 1976). The top instrument on each mooring was equipped with a pressure sensor.

The T/P contains a thermistor and pressure sensor. Temperature accuracy is about .01°C; pressure accuracy is .03% of sensor full scale.

Both the VACM and T/P contain a crystal oscillator with an accuracy of ± 1 second per day to set the time base and record on Phillips-type cassettes with Sea-Data recorders.

Data Quality

Except for mooring 619, which was lost, data recovery was excellent. There were two problems, both with pressure: in record 6161 the pressure signal drifted 12 decibars or 11 months; in record 6181 the pressure signal ceased after 4 months.

Data Processing

The cassettes were transcribed to 9-track computer compatible tapes, and the data were converted to scientific units, edited to remove launch and retrieval transients, and linearly interpolated across missing or erroneous data cycles.

The data are identified by a mooring number (here 616-620), a sequential instrument numbered from the surface down (e.g., 6163 is the third instrument down on mooring 616), a letter to indicate the data version (e.g., 6163C has been through three editing steps), and a number to indicate the data interval in seconds for that version (e.g., 6163C900is the basic data series). 1H in place of the number indicates a one-hour averaged version, 24 GAU indicates a 24 hour subsampled version of a Gaussian filtered series.

The T/P data were processed by the T/P processing group at M.I.T. They are identified by a mooring and instrument number and a data record time interval.

Data Presentation

The presentations in this report are time series, progressive vector plots, spectra, mean statistics, histograms, and scatter plots. Additional details are below. Composite plots appear in the printed portion of the report. Presentations for individual data files are presented only in the microfiche portion.

Time Series

The presentations use several averaging times. The 1 hour version is made by vector averaging the 900 s basic series. To make the 24 hour series, the basic time series is first filtered using a symmetrical running Gaussian filter with a half width of 24 hours. The filtering is sequential and the resultant time series is 48 hours shorter than the input time series. A simple running hat filter is then applied to form a series with one data point per day, the point representing the average from midnight to midnight.

Variables versus time (pages 24-30) and current vectors ("stick plots") versus time (pages 16-19) are presented. The former are based on 1 hour averaged series subsampled every 4 hours, the latter on the 24 hour series. Current variables are presented as speed and direction in the microfiche portion of the report.

Progressive Vectors

Based on the 24 hour series, the current vectors are placed tail-to-head so as to show the path that a perfect particle in a perfectly homogeneous fluid would have traveled. The plots (pages 20-23) are useful for giving an idea of flow regimes and low frequency behavior. Symbols denote the end of a month.

Spectra

The horizontal kinetic energy (HKE) and (where available) the temperature and pressure series are displayed as spectra computed from the basic series.

The horizontal kinetic energy spectrum is half the sum of the spectra of the east and north components: it has the advantage of not being tied to a particular coordinate system.

The HKE, temperature, and pressure spectra have units of (cm^2/sec^2)/cph, $(°C)^2$/cph, or $(dbar)^2$/cph, respectively. The spectra are all one-sided, i.e. the area under the spectrum is equal to the variance of the original record. The spectra are presented as linear-log plots ("variance preserving") in the printed portion of the report (pages 31-42) and as log-log plots (not "variance preserving") in the microfiche portion.

The current meter spectra are all calculated based on averaging across four data segments of 4000 points each, followed by frequency-band averaging across three frequencies with a recording interval of 900 s. This gives a lowest frequency of $(666.7h)^{-1}$ and a highest frequency of $(0.5h)^{-1}$. The TP spectra are based on averaging across two data segments of 4000 points each, followed by frequency band averaging across three frequencies. With a recording interval of 1800 s this gives a lowest frequency of $(1333.3h)^{-1}$ and a maximum frequency of $(1h)^{-1}$. No data-windowing or prewhitening has been done.

TIMSAN, the W.H.O.I. program (Hunt, 1978) used to produce the spectra, additionally averages the spectra in increasing groups at the higher frequencies to prevent having to plot thousands of points; this gives few degrees of freedom (d.o.f) at the lowest frequencies, many at the highest frequencies. For spectra calculated from 4 pieces with 3 frequencies averaged, there are 24 d.o.f. in the 40 lowest frequencies and 1200 d.o.f. in the two highest frequencies; the 95% confidence limits corresponding to these two extremes are (.61, 1.94) and (.97, 1.03).

Mean Statistics

The statistics for each variable for the time period shown are given for the basic series, also the east and north covariance, correlation, and vector statistics on pages 44-45.

For reference note that a Gaussian random variable would have a kurtosis of 3 and a skewness of zero.

Histogram

Each variable is plotted as relative frequency of occurrence (in the basic series) per unit cell width versus amplitude on pages 43-55; the area under the histogram is 100%. The mean value is marked on the horizontal axis.

Scatter Plots

Scatter plots of north vs. east component, and temperature vs. east component and vs. north component are shown for each current meter record on pages 56-77.

Acknowledgments

The work of the moored array group in organizing, deploying, and recovering the Western Boundary Undercurrent array is gratefully acknowledged, together with the efforts of the personnel aboard R/V Knorr, R/V Oceanus and R/V Atlantis II, and of Larry Armi, who was co-chief scientist of R/V Oceanus-31.

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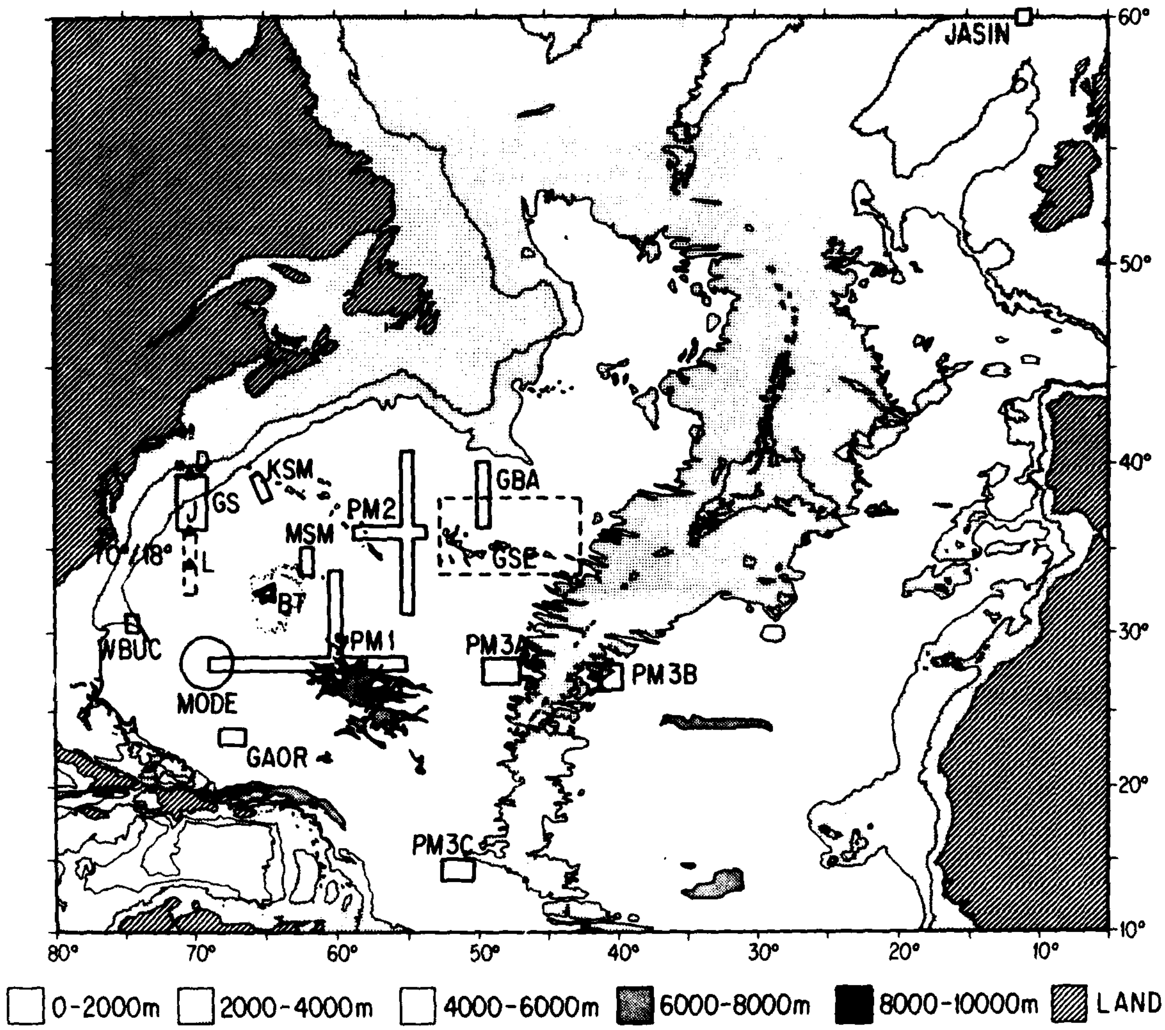


Figure 1: Locations of North Atlantic observations. Key: Past and present observations: JASIN = Joint Air-Sea Interaction Experiment, D = Site D, J = Site J, L = Site L, GS = Gulf Stream Array, KSM = Kelvin Seamount Experiment, MSM = Muir Seamount Experiment, BT = Bermuda Triangle Array, WBUC = Western Boundary Undercurrent Experiment (the present investigation), MODE = Mid-Ocean Dynamics Experiment, GAOR = Greater Antilles Outer Ridge Experiment, PM1 = POLYMODE Array 1, PM2 = POLYMODE Array 2, PM3A, -B, -C = POLYMODE Array 3, Clusters A, B, C, GBA = Grand Banks Array. Proposed observations: GSE = Gulf Stream Extension and Norwegian Sea Overflow Intrusion Array, 70°W/18° = 70°W/18° Water/Eckart Resonance Array.

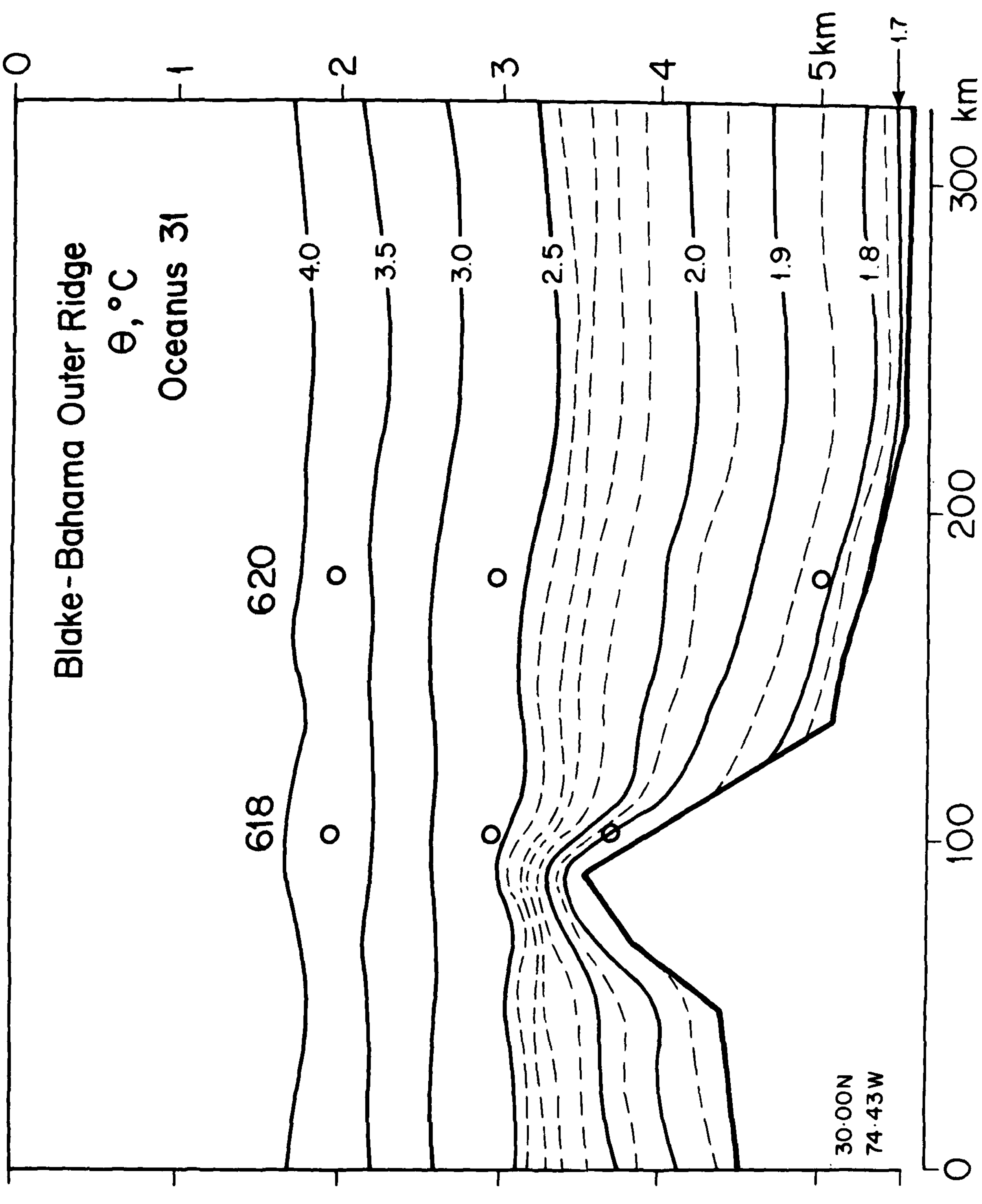


Figure 2: Potential temperature section across the Blake-Bahama Outer Ridge (8 August 1977). The track is indicated on fig. 2. Current-meter locations are shown. The deep boundary current flows southward along the eastern slope of the Ridge, and returns northward on the western slope. The mooring records show, however, that the long-term mean flow is narrower than would be inferred from the region of tilted isotherms (at 620 the 12-month mean is northwestward: fig. 4, and page 14).

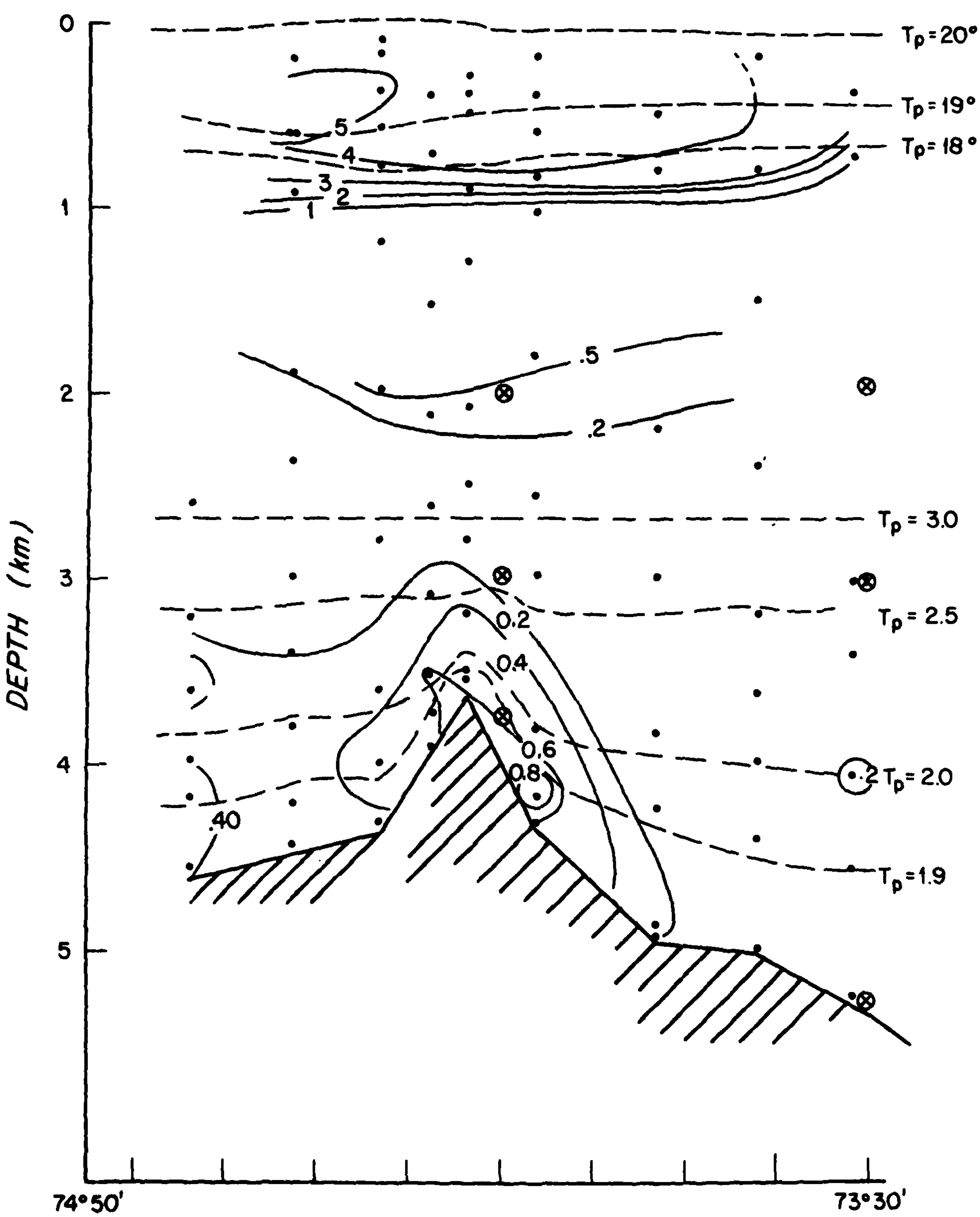
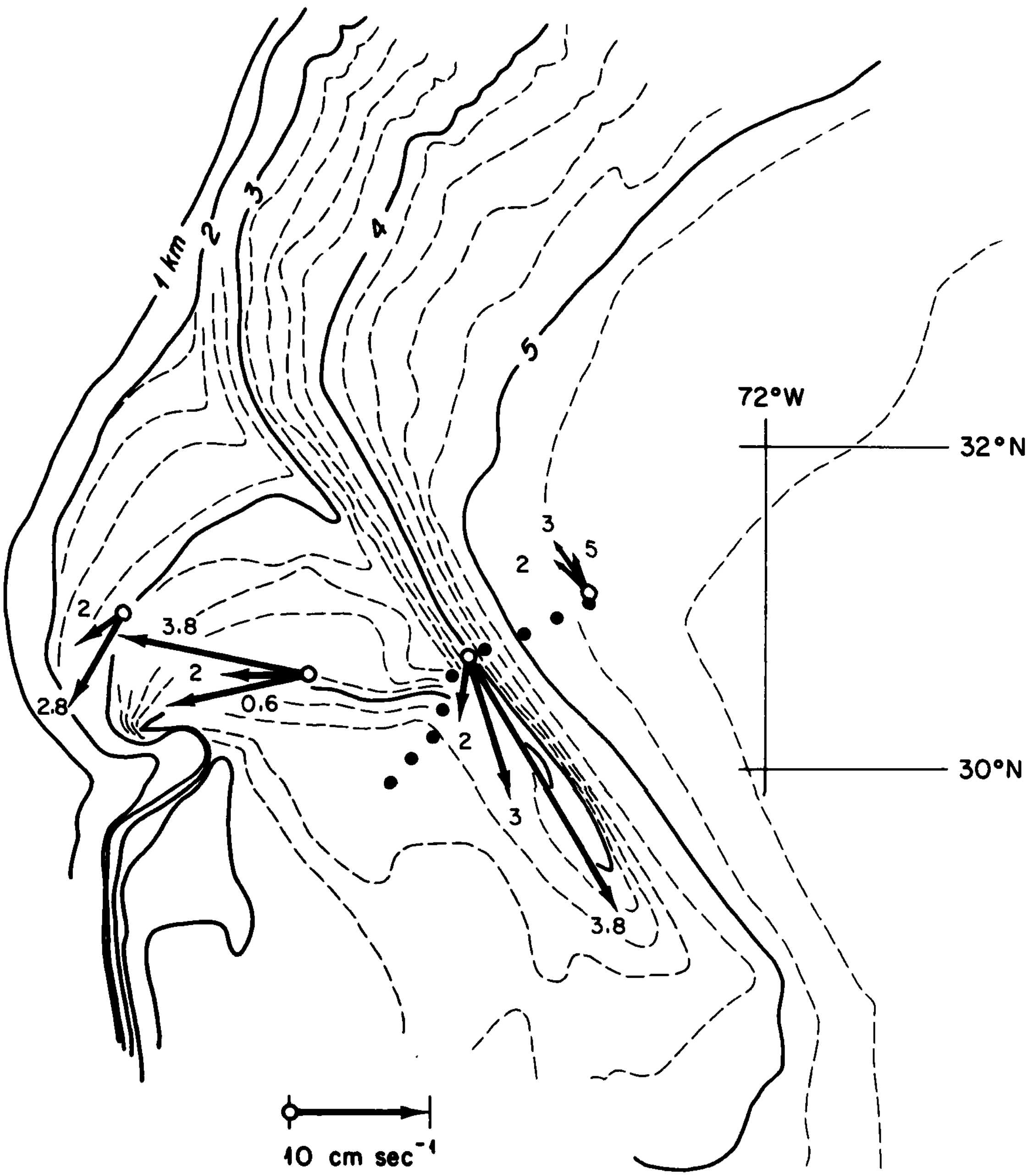


Figure 3: Tritium concentration, showing the high values associated with the deep boundary current. Dashed curves are potential isotherms. The tritium concentration essentially vanishes at 3000 m, and rises once again above the thermocline. A subsurface maximum is seen in the 18° water, associated with recent winter renewal farther north.



12-MONTH MEAN CURRENT

Figure 4: 12 month mean currents from the four moorings. Depth of current meter in km. The deep jet follows the bottom topography. The weaker flow at mid-depth veers in the sense of a stratified Taylor column allowing some flow to rise up over the Ridge crest. The 600 m level flow is consistent with the general circulation, feeding into the Gulf Stream. The northwestward mean at the easternmost mooring is consistent with Worthington's deep-water anti-cyclone.

TABLE I

Summary of Mooring Locations and Dates

Mooring #	Location (°N) (°W)	Cruise KNORR 66 Date Set (1977)	Cruise A-II-100 Date Recovered (1978)	Bottom Depth (m)	Days At Sea
616	30° 59.90 76° 39.0	May 14	May 5	2993	357
617	30° 31.0 75° 05.5	May 14	May 6	3801	358
618	30° 43.2 74° 10.37	May 15	May 13	4002	354
619	LOST				
620	31° 03.5 73° 23.5	May 15	May 2	5187	353

TABLE II

Summary of Presented Data

Record #	Type of Inst.	Depth (Corrected) (m)	Duration (Days)	Dates (1975-1976)	Number of Points
6161	VACM/P	1995	356	May 14-May 5	34208
6162	T/P	1996	356	May 14-May 5	17064*
6163	VACM	2796	356	May 14-May 5	34192
6171	VACM/P	601	356	May 14-May 5	34188
6172	VACM	2002	356	May 15 May 6	34178
6173	VACM	3602	356	May 15-May 6	34161
6181	VACM/P	2002	353	May 15-May 3	33858
6182	VACM	3003	353	May 15-May 3	33888
6183	VACM	3802	353	May 15-May 3	33880
6201	VACM/P	1958	351	May 16-May 2	33698
6202	VACM	2958	351	May 16-May 2	33696
6203	VACM	4987	351	May 16-May 2	33698

* Sampling rate for 6162 is 1800 sec. Sampling rate for VACM and VACM/P is 900 sec.

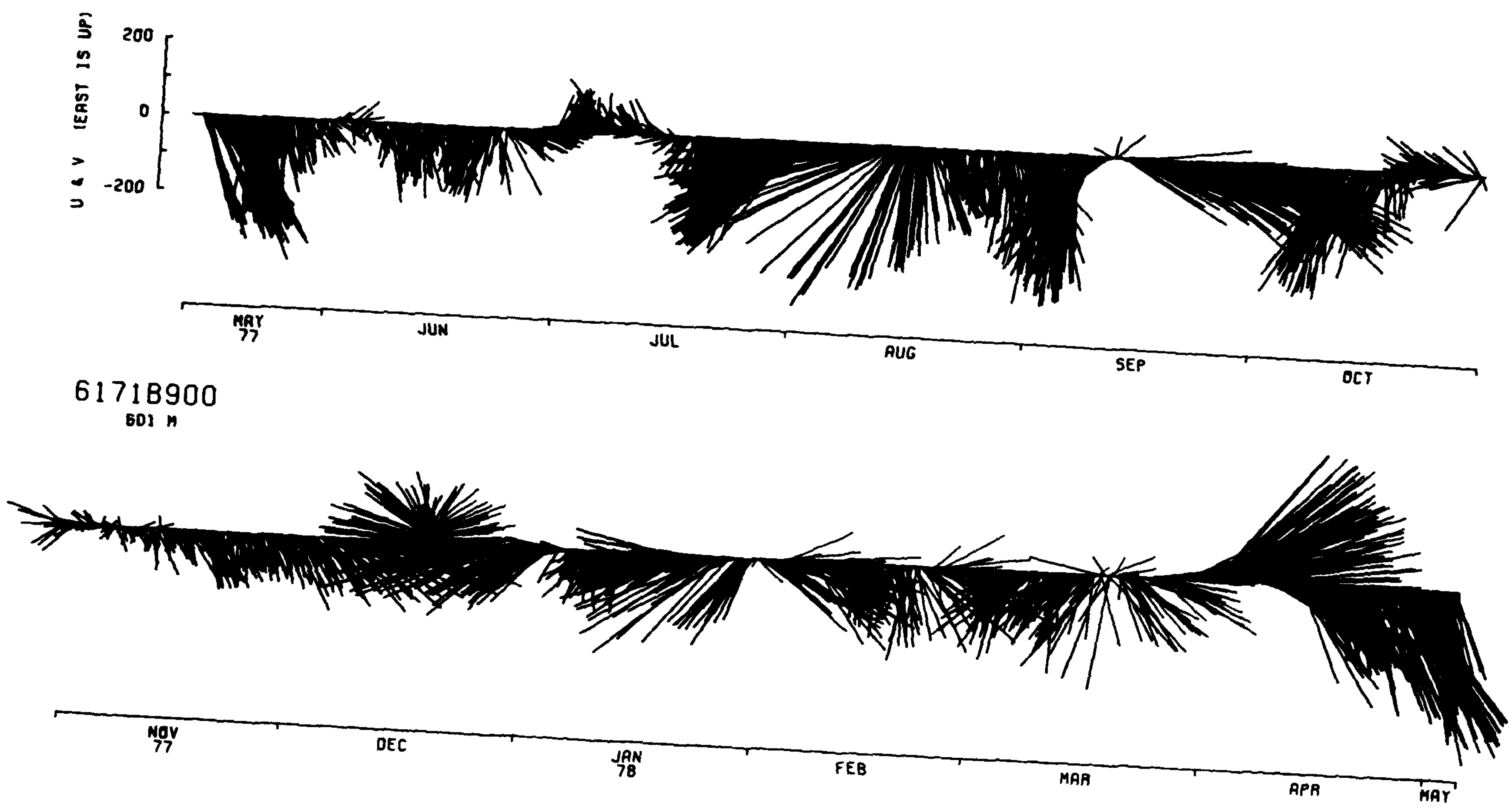


Figure 5: Velocity time-series at 601 m, showing cold Gulf Stream rings and larger warm lenses passing westward across the array (East = up).

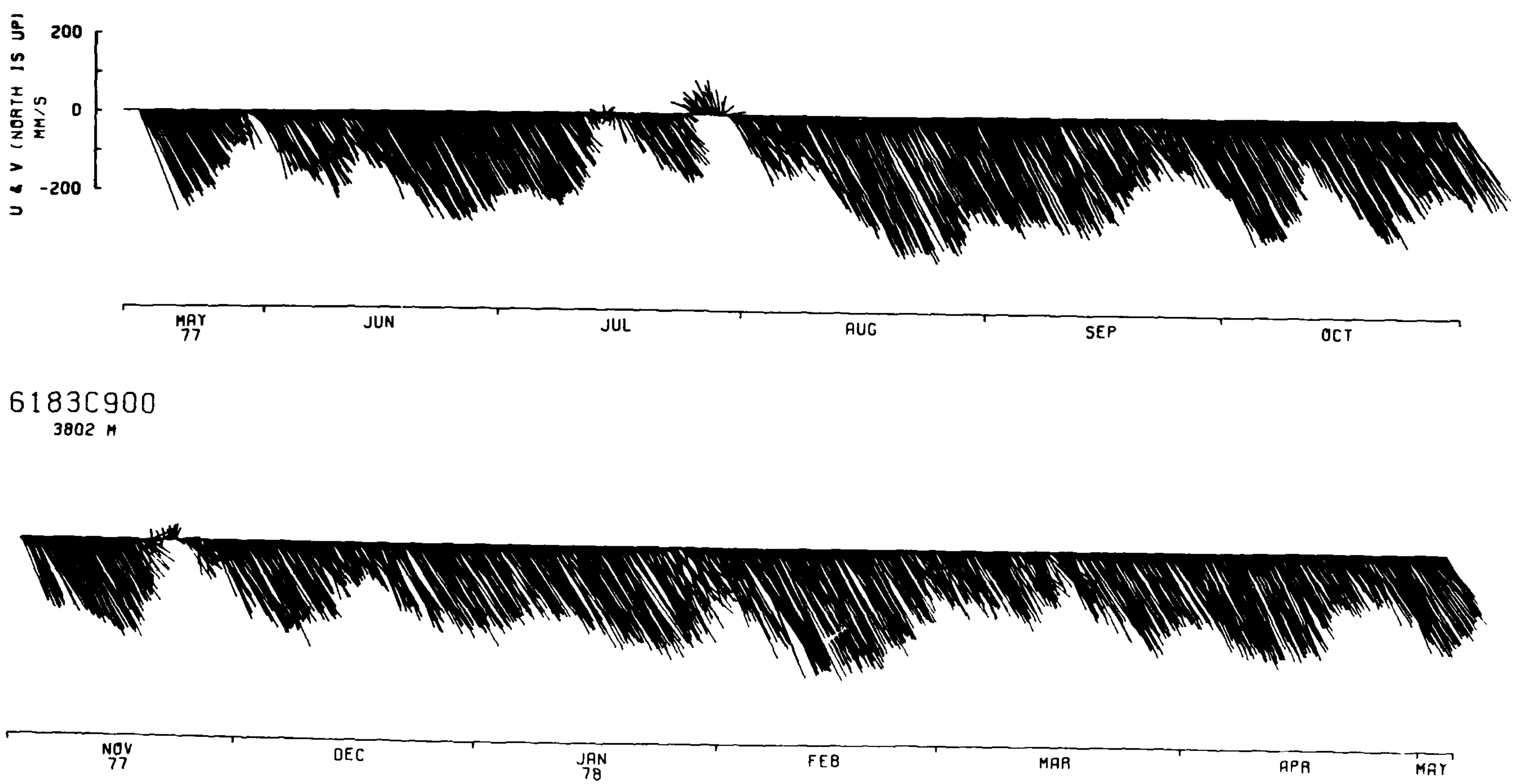
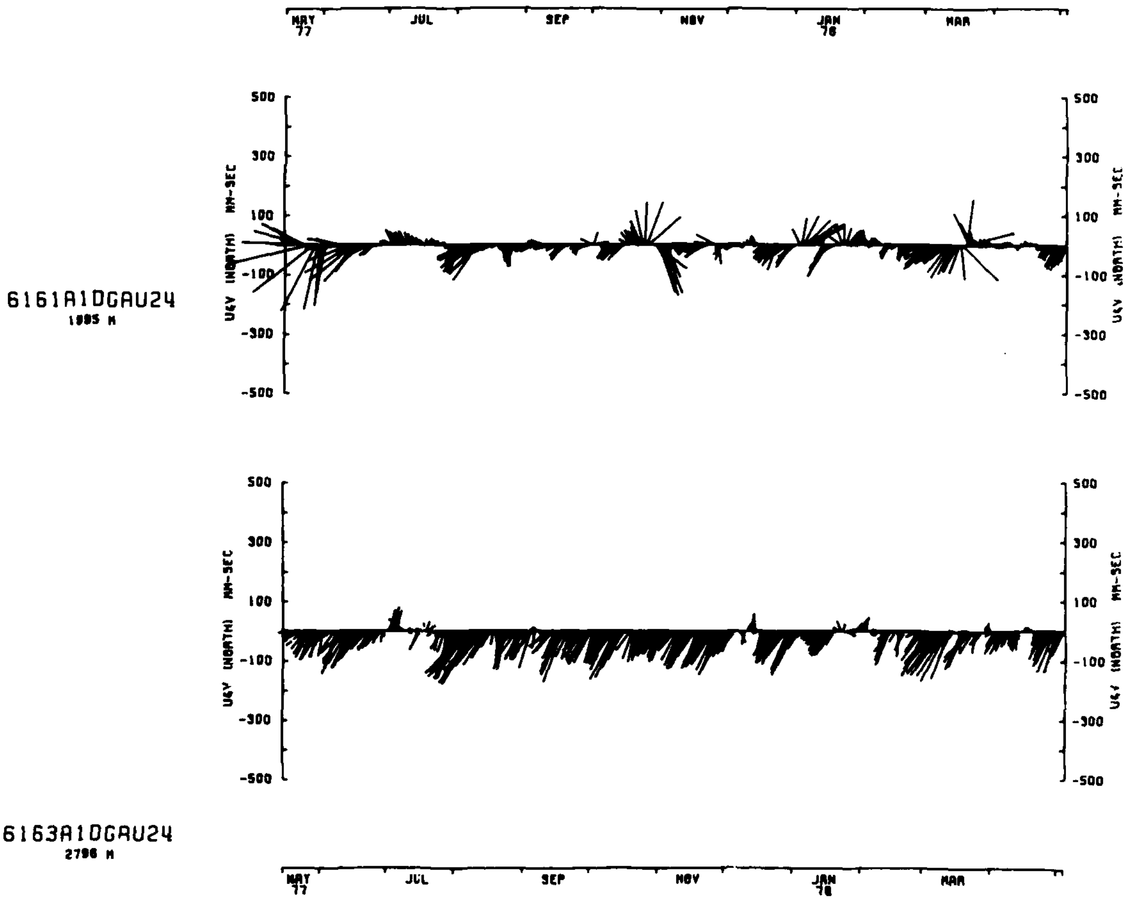


Figure 6: Velocity time-series 200 m above bottom in the core of the deep jet. The mean flow is well-defined, yet surges and periods of reversed flow occur. The mean flow is nearly parallel to the depth contours, but during surges the flow gains an upslope component (see page 70 also).

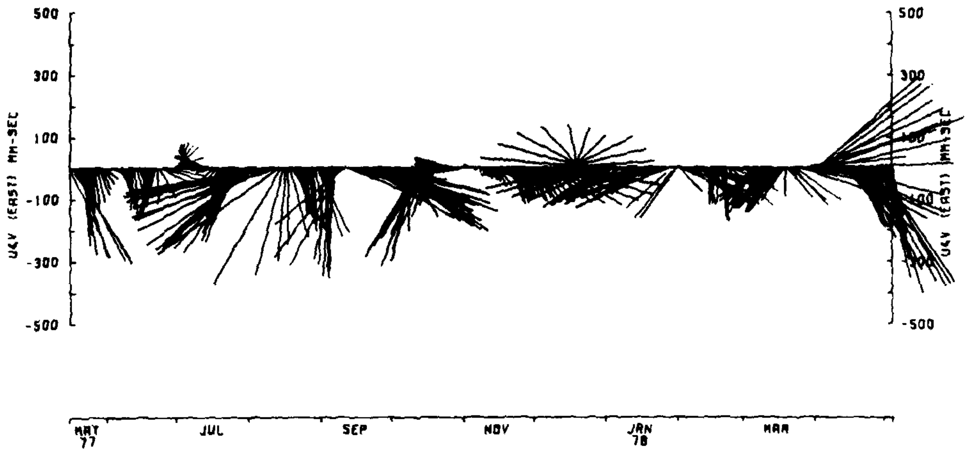
DATA

PRESENTATION

CURRENT VECTORS   MOORING 616



CURRENT VECTORS MOORING 617



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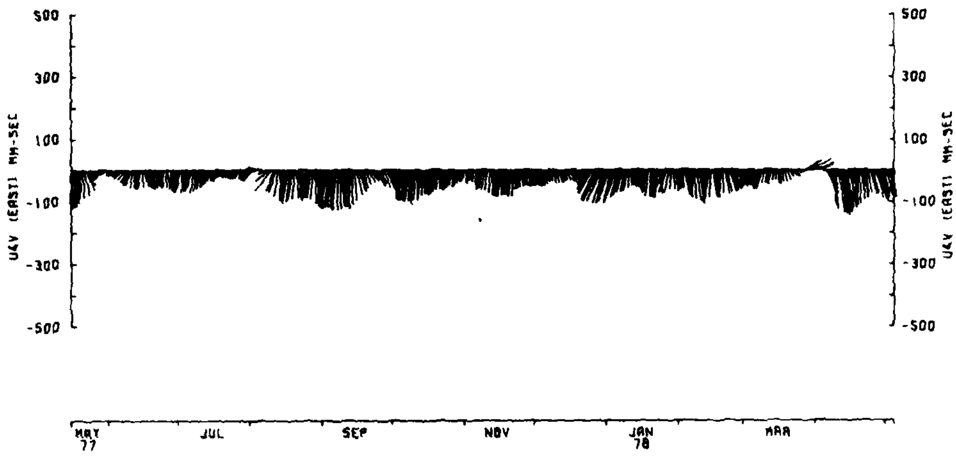
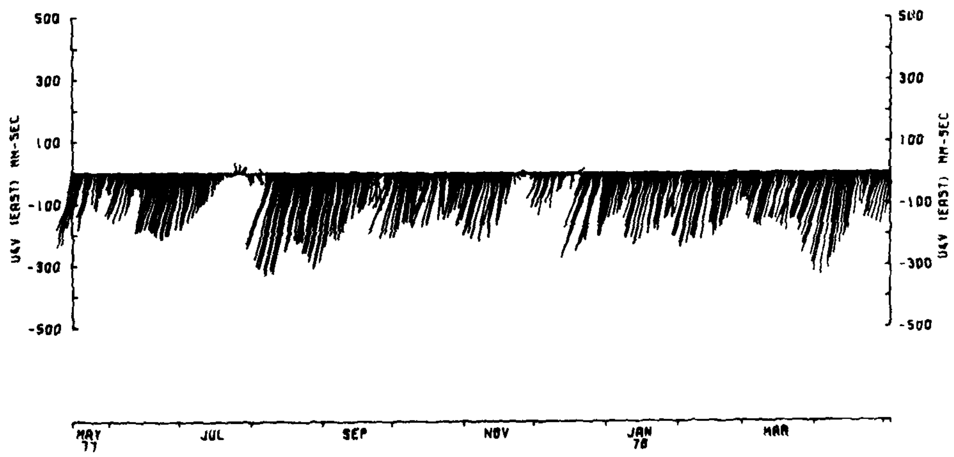
601 M

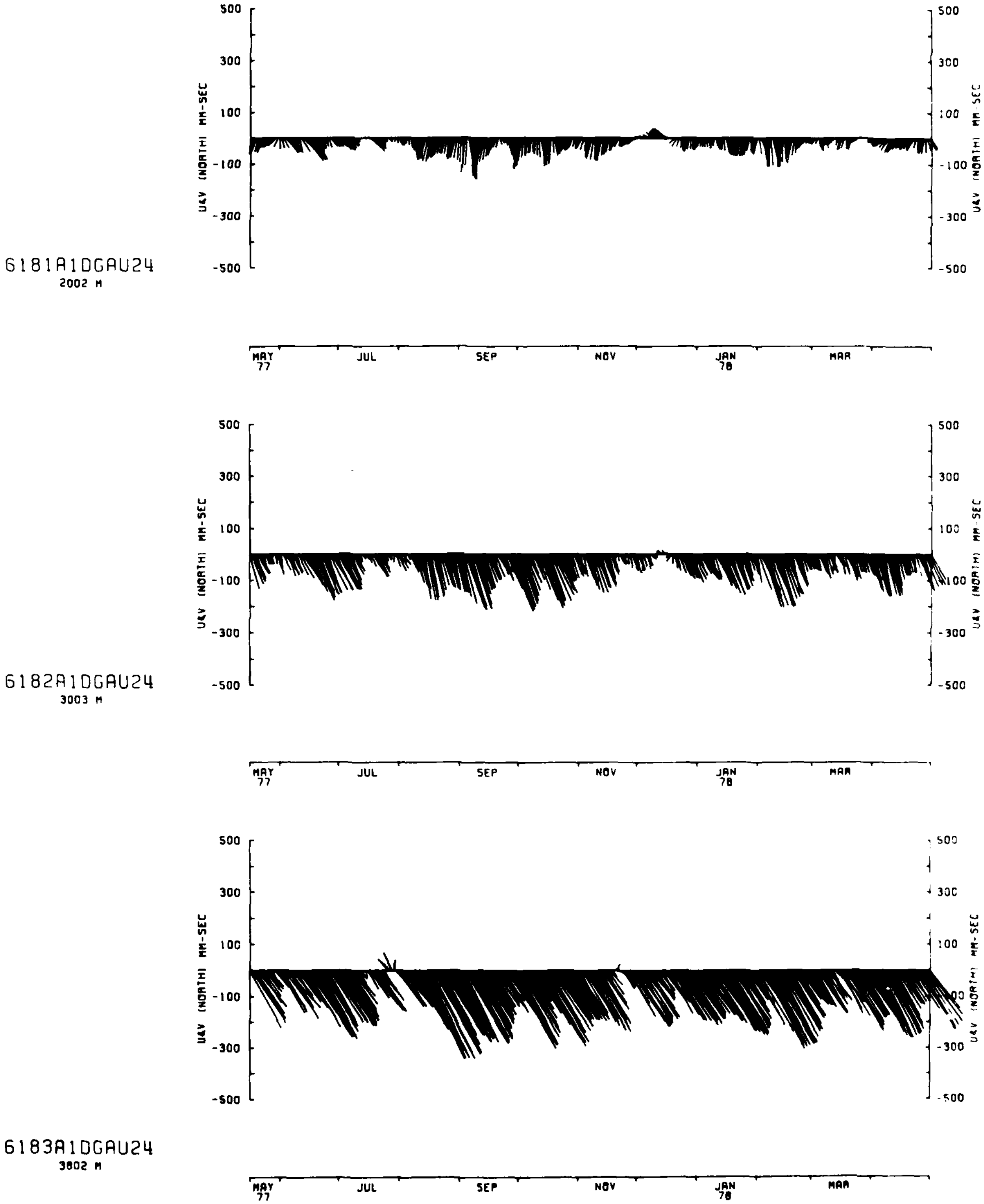


6172A1DGAU24
2002 M

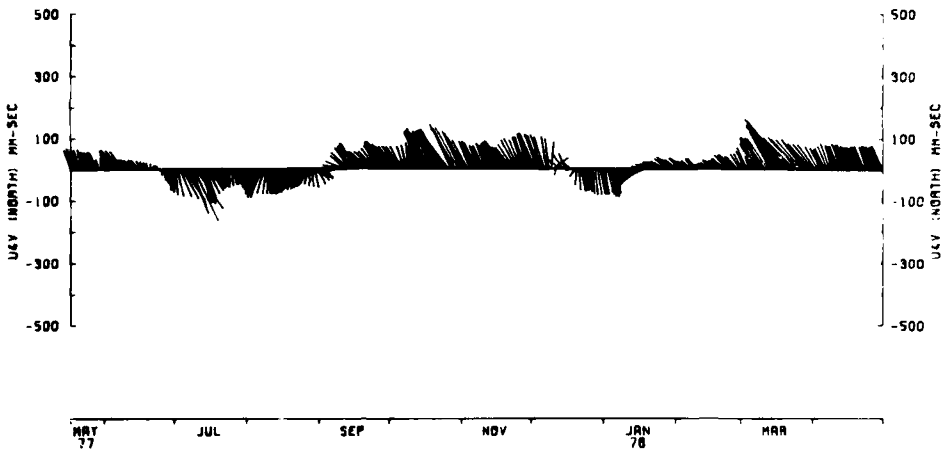


6173A1DGAU24
3602 M

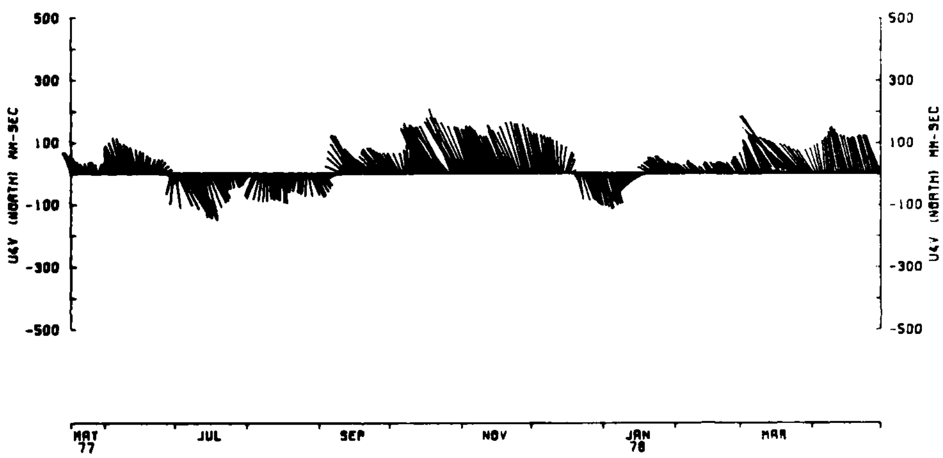
CURRENT VECTORS MOORING 618



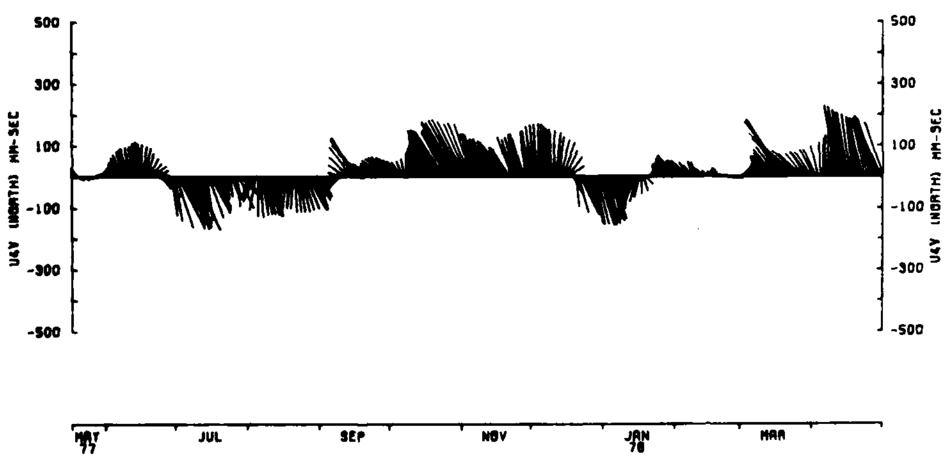
CURRENT VECTORS MOORING 620



6201A1DGAU24
1950 M

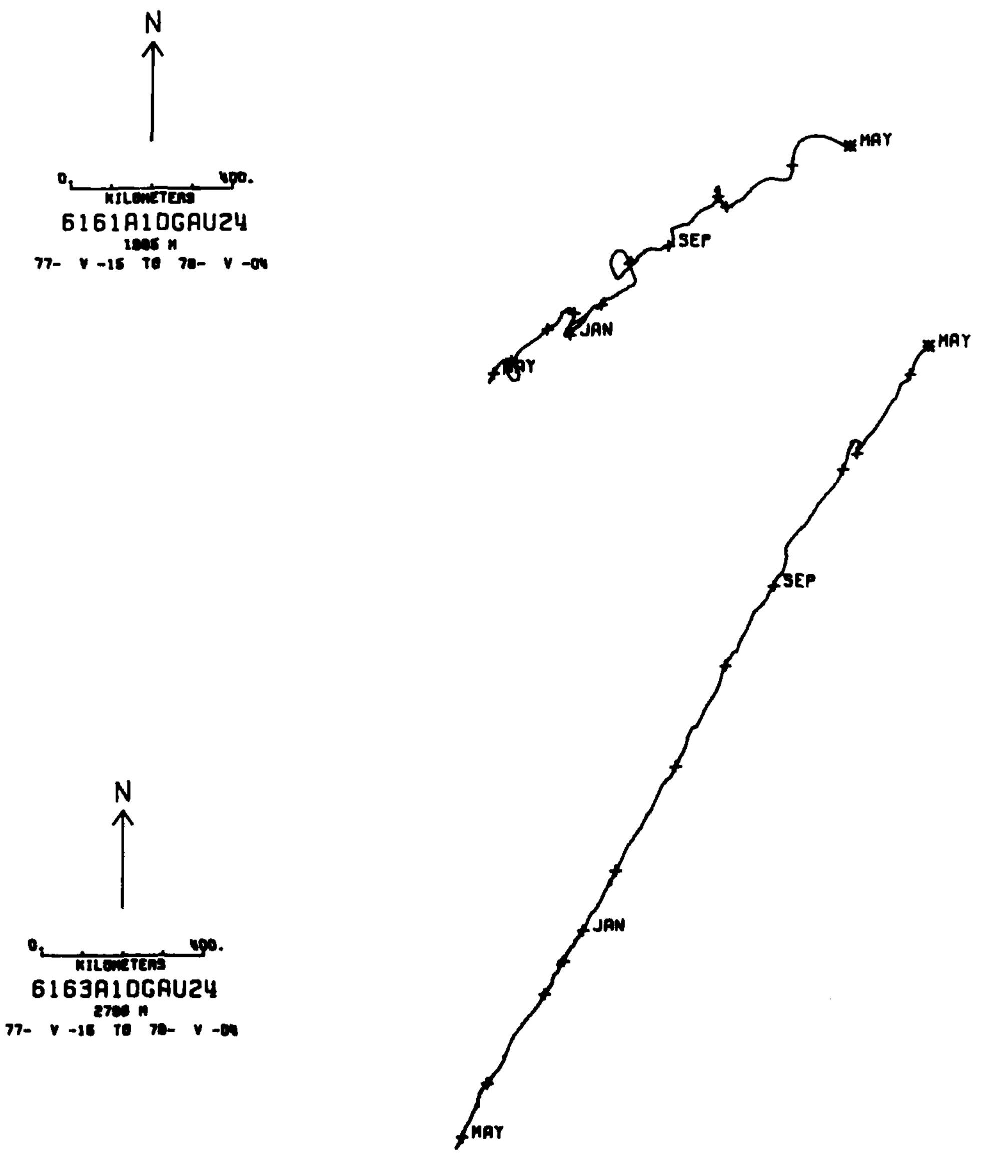


6202A1DGAU24
2950 M

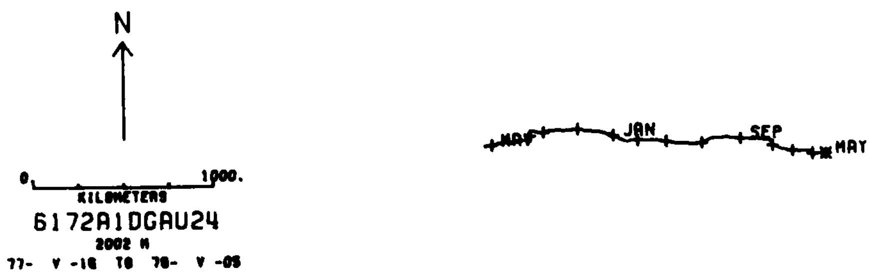


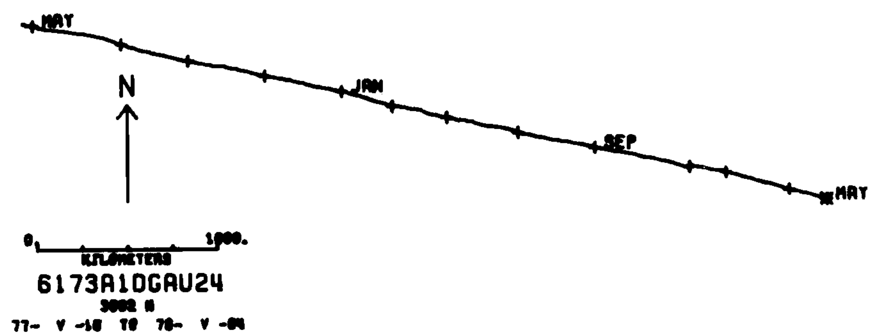
6203B1DGAU24
4907 M

PROGRESSIVE VECTORS MOORING 616

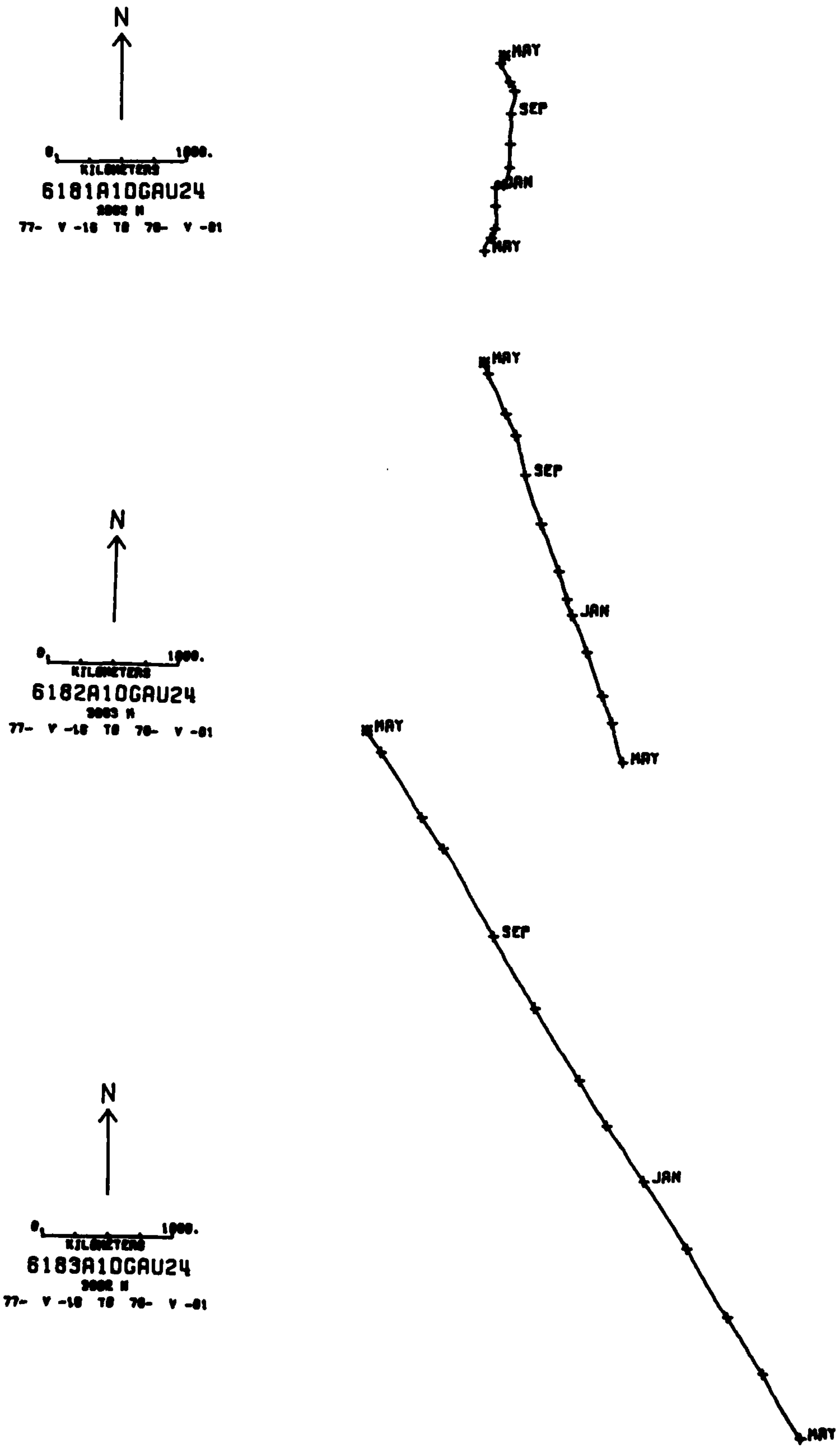


PROGRESSIVE VECTORS MOORING 617

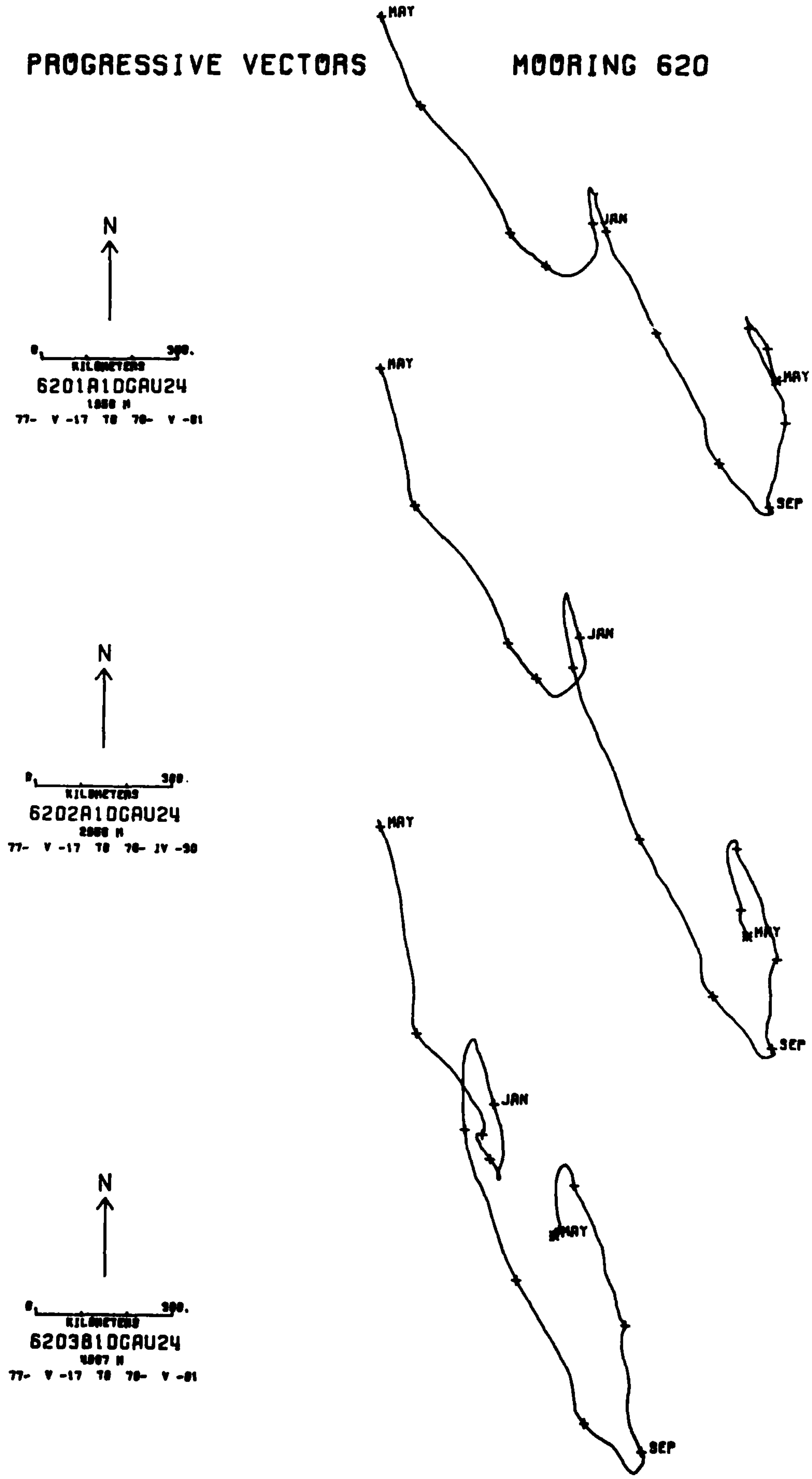




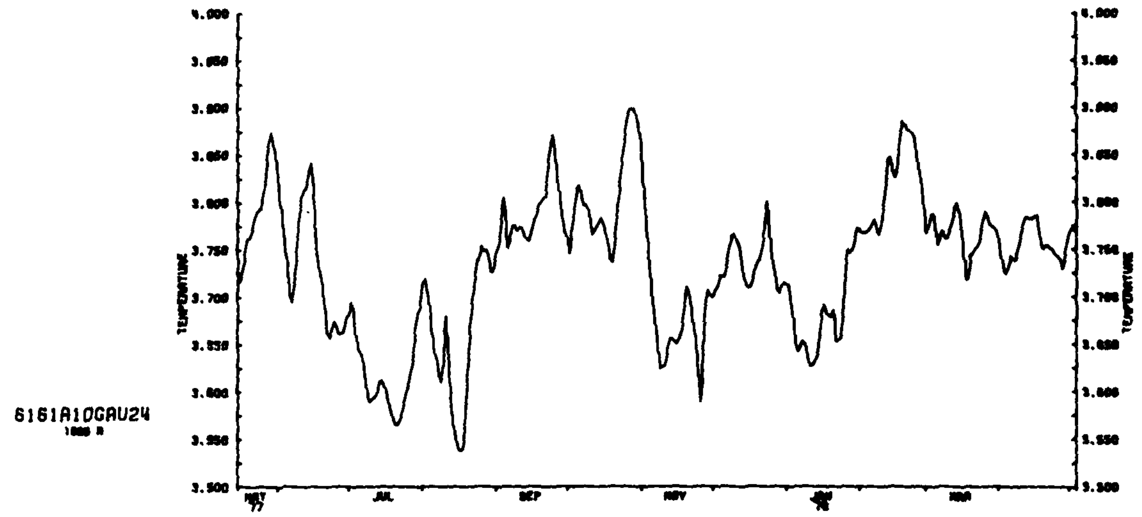
PROGRESSIVE VECTORS MOORING 618

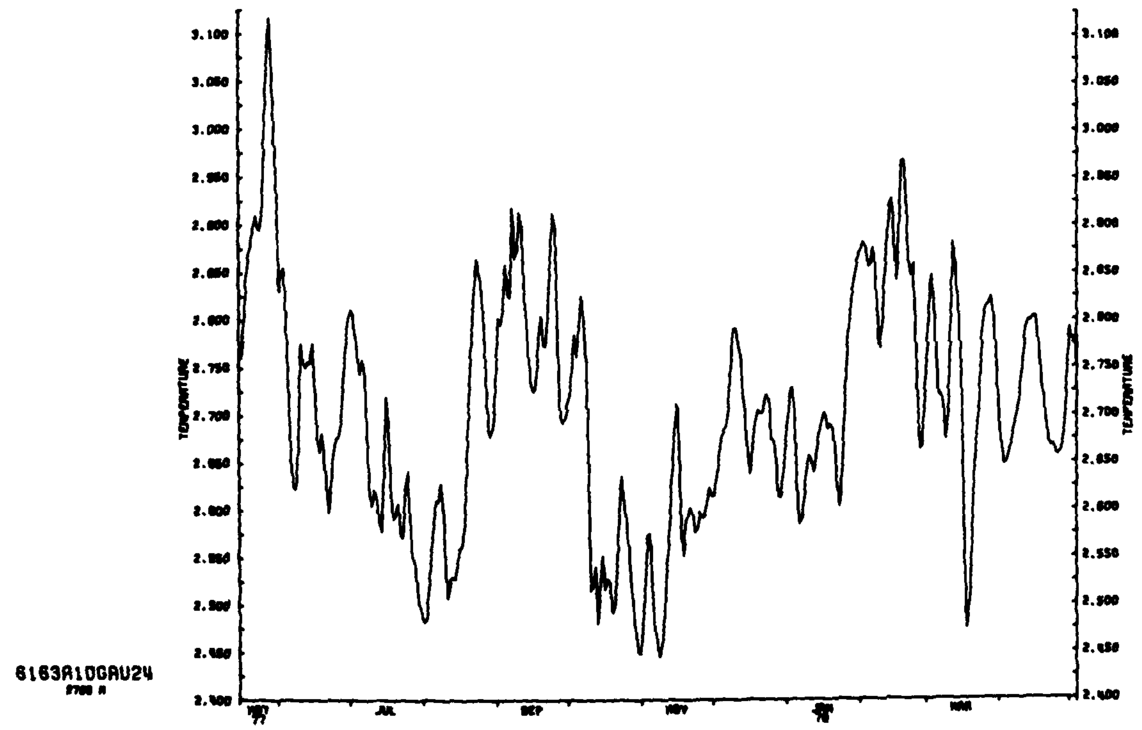


PROGRESSIVE VECTORS MOORING 620

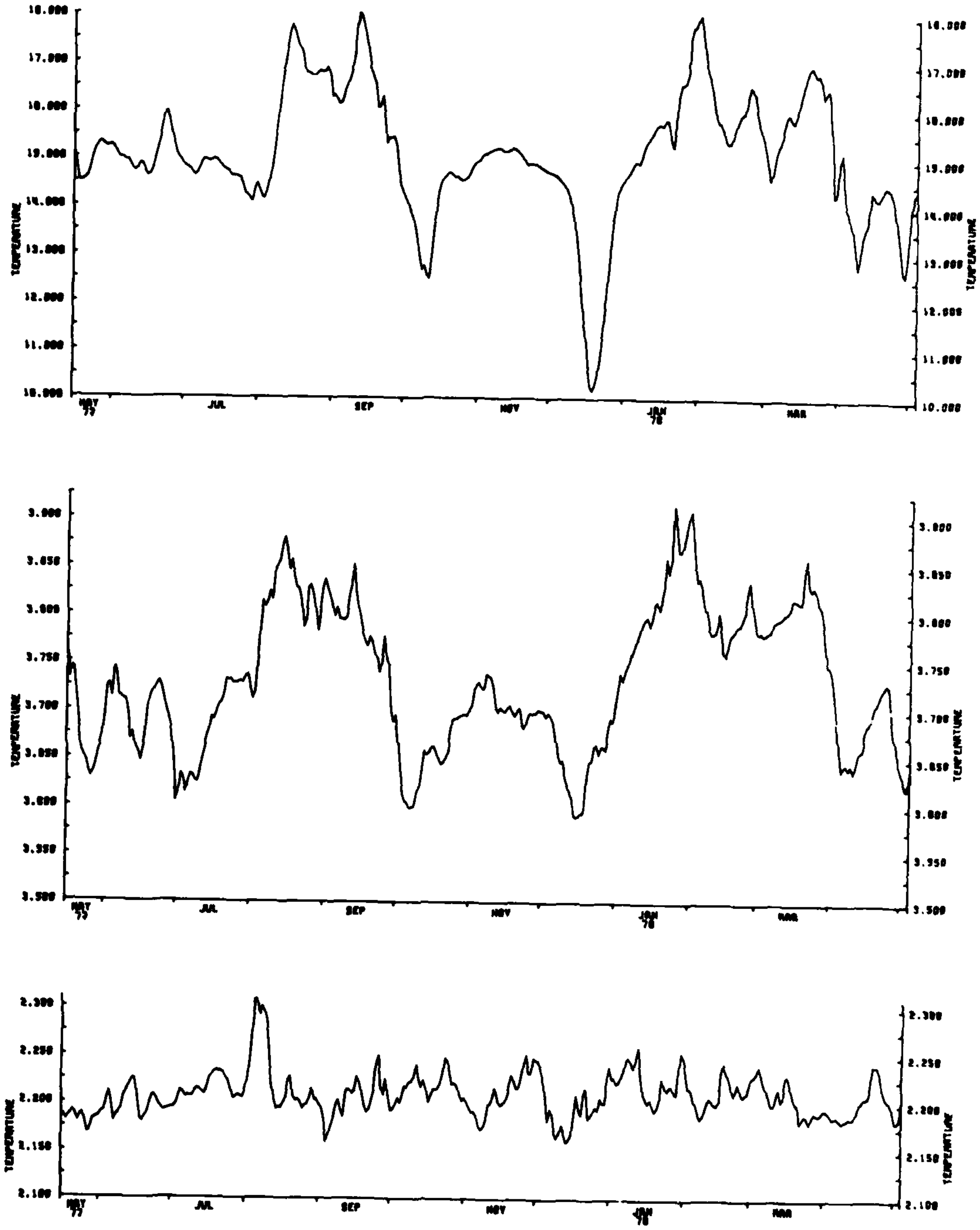


TEMPERATURE MOORING 616





TEMPERATURE MOORING 617

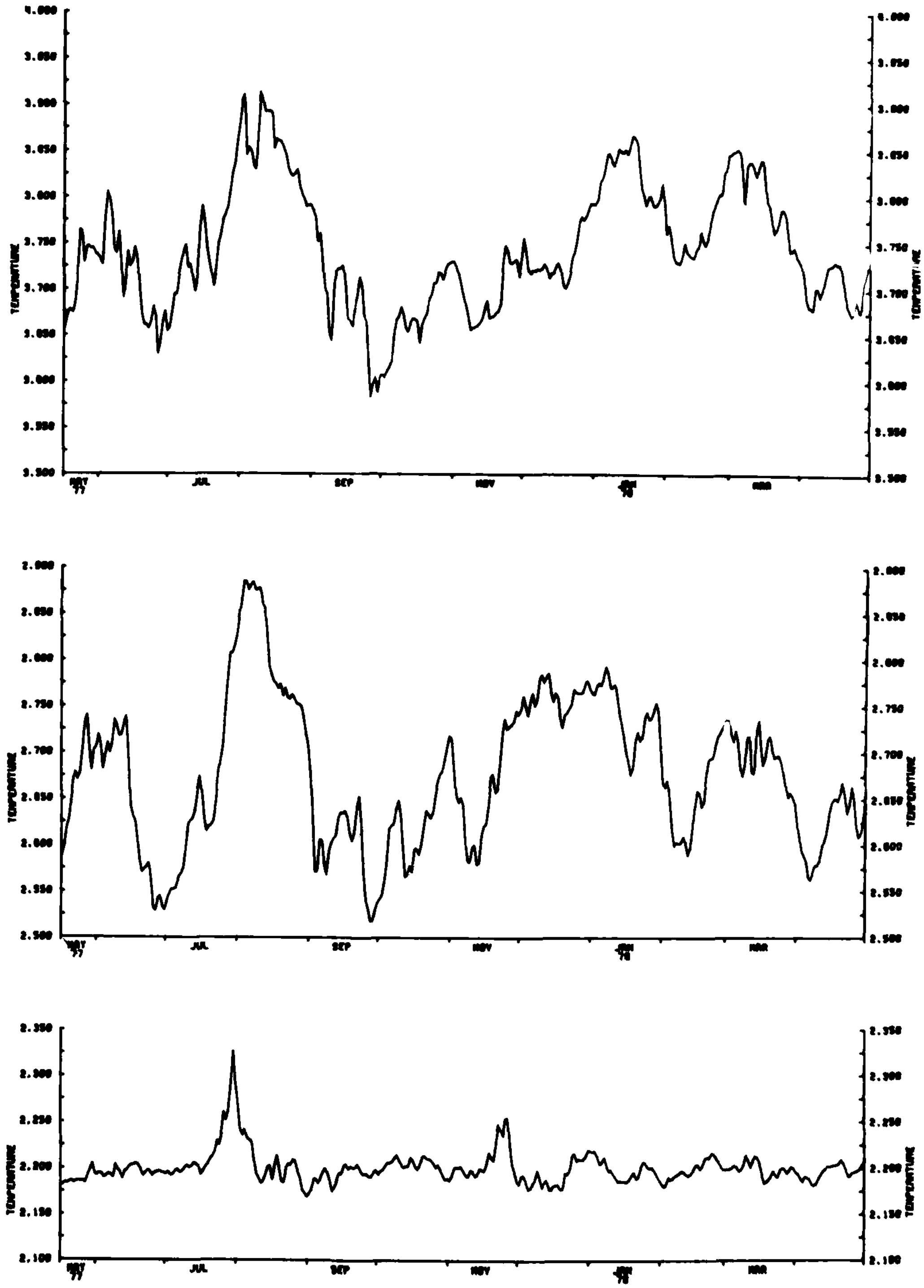


6171B1DGAU24

6172A1DGAU24

6173A1DGAU24

TEMPERATURE MOORING 618

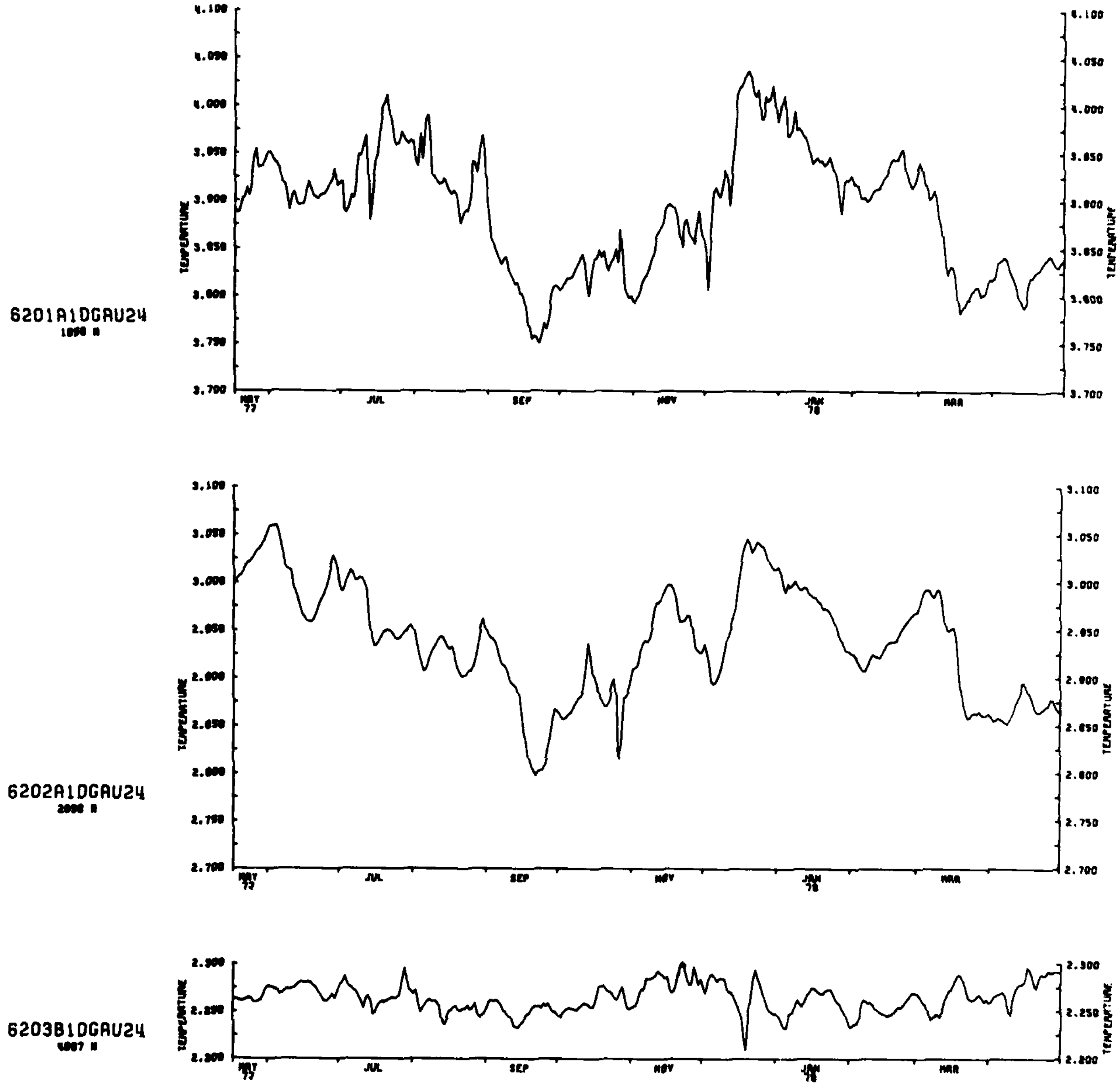


6181A1DGAU24

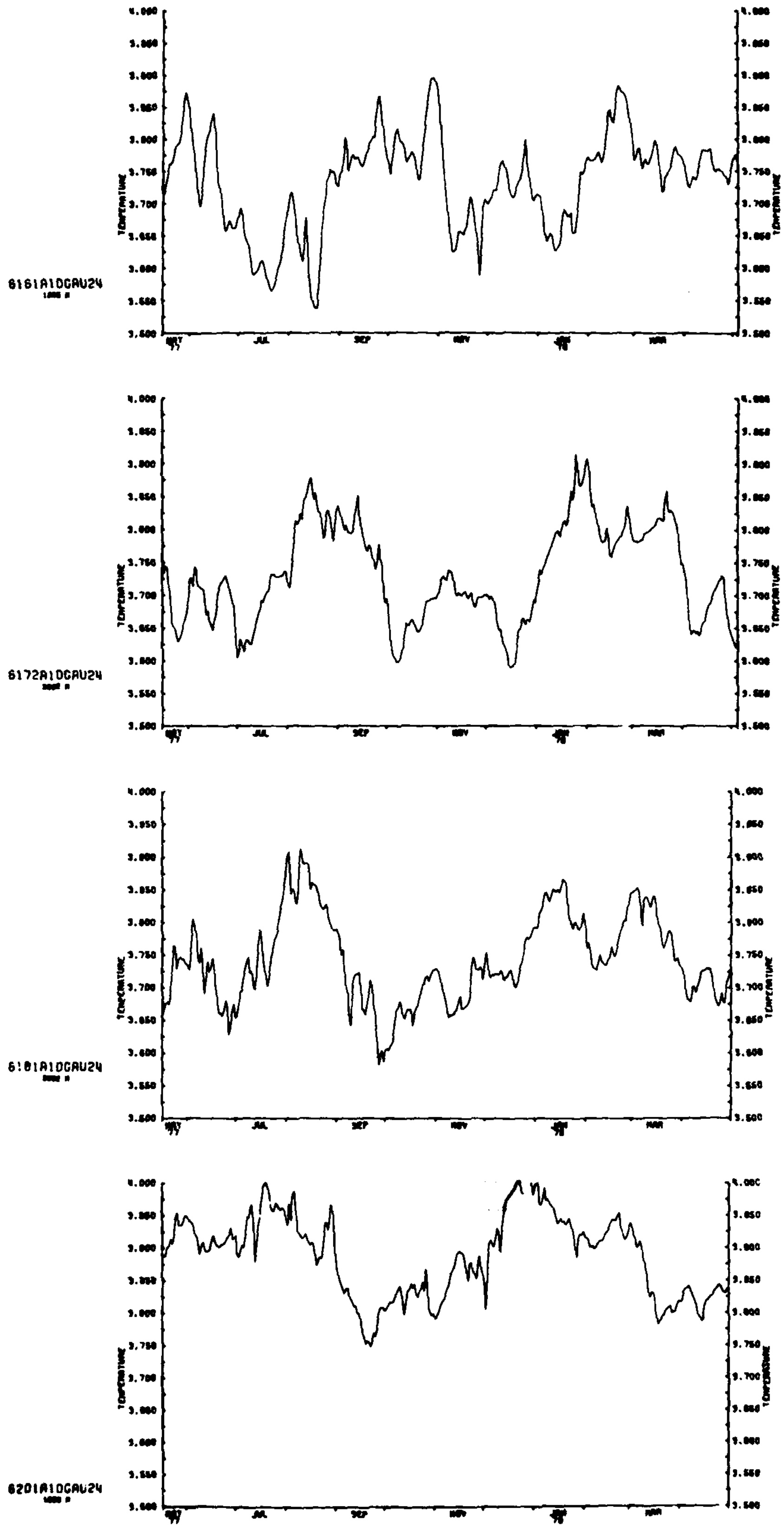
6182A1DGAU24

6183A1DGAU24

TEMPERATURE MOORING 620

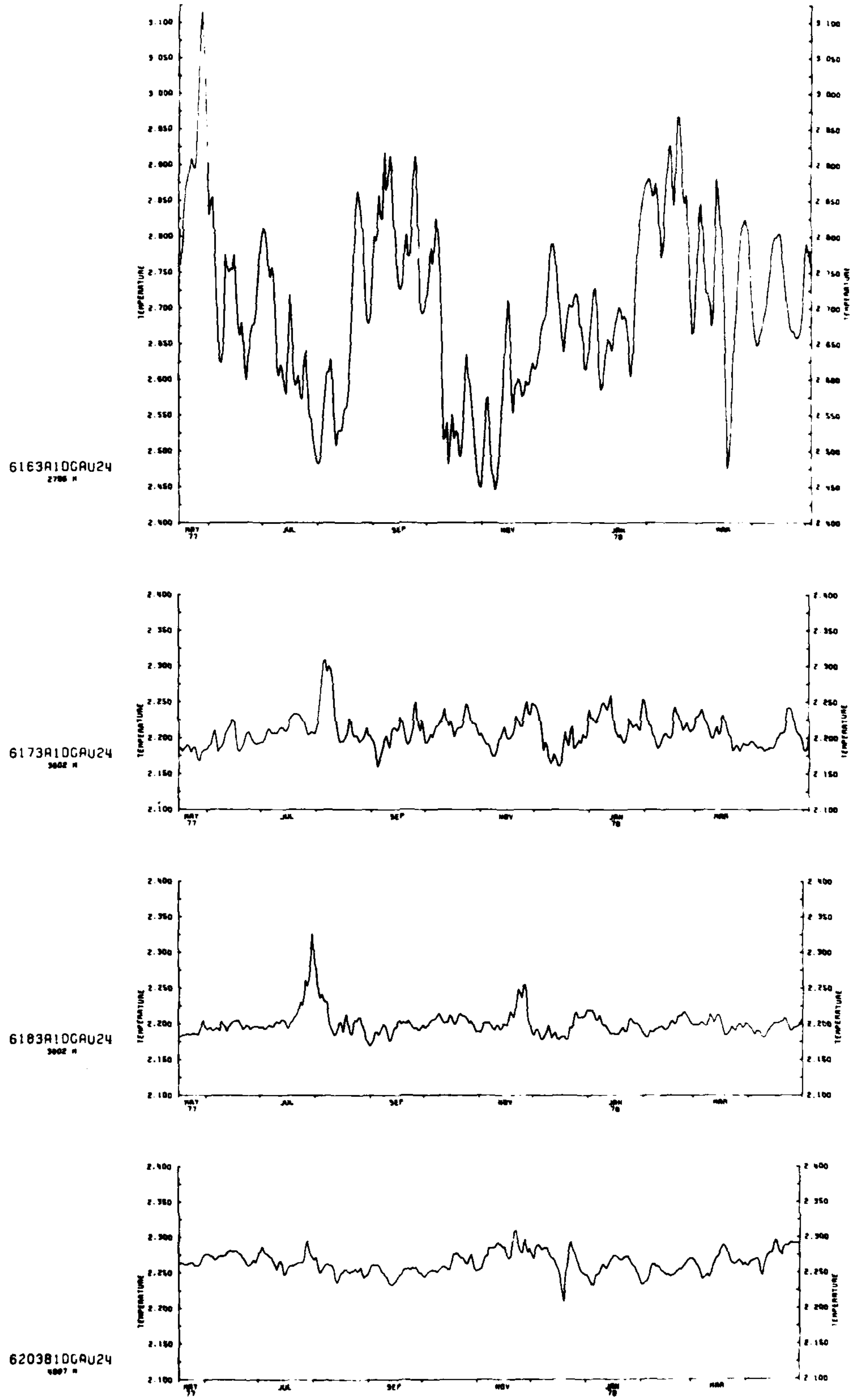


TEMPERATURE DEPTH: 2000



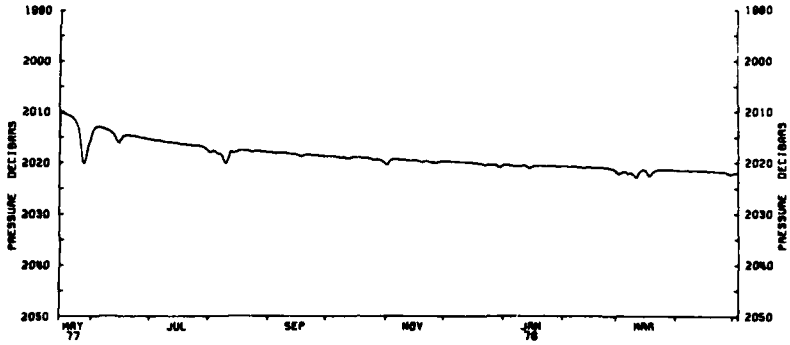
2000 m temperatures. Note the apparent westward propagation of coherent warm eddies across the array (despite large spacing between moorings).

TEMPERATURE BOTTOM INSTRUMENT (200M FROM BOTTOM)

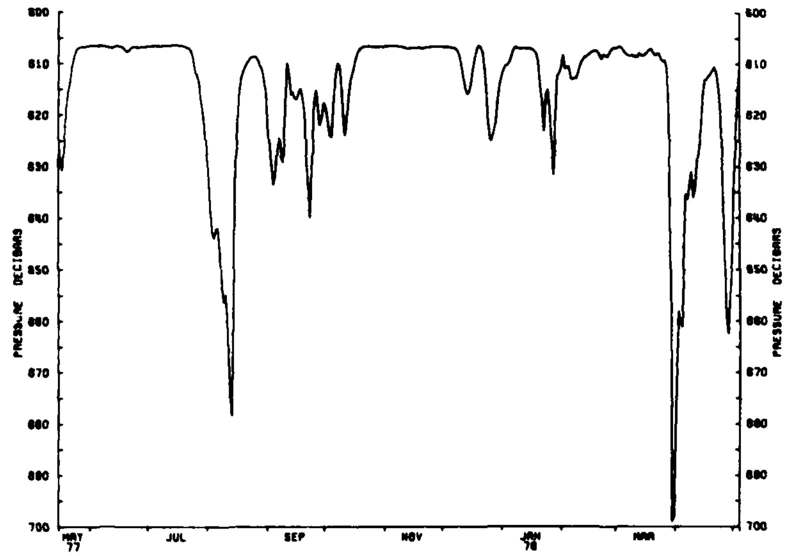


Near-bottom temperatures. The pulse-like rises occur when the deep flow shuts off or reverses. This is associated with the arrival of 'warm fronts' above the thermocline (the leading edge of large, warm eddies in the 18°-water).

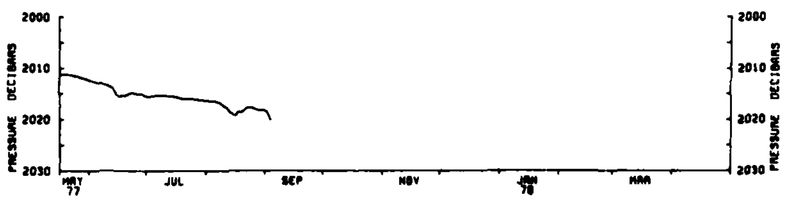
PRESSURE



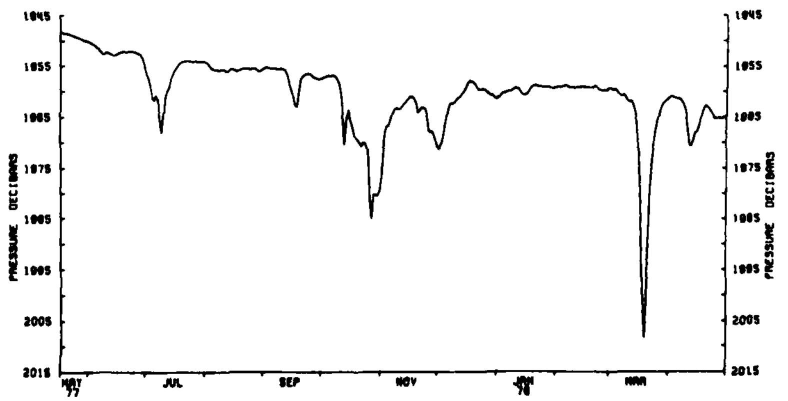
6161A1DGAU24
[illegible] M



6171B1DGAU24
601 M

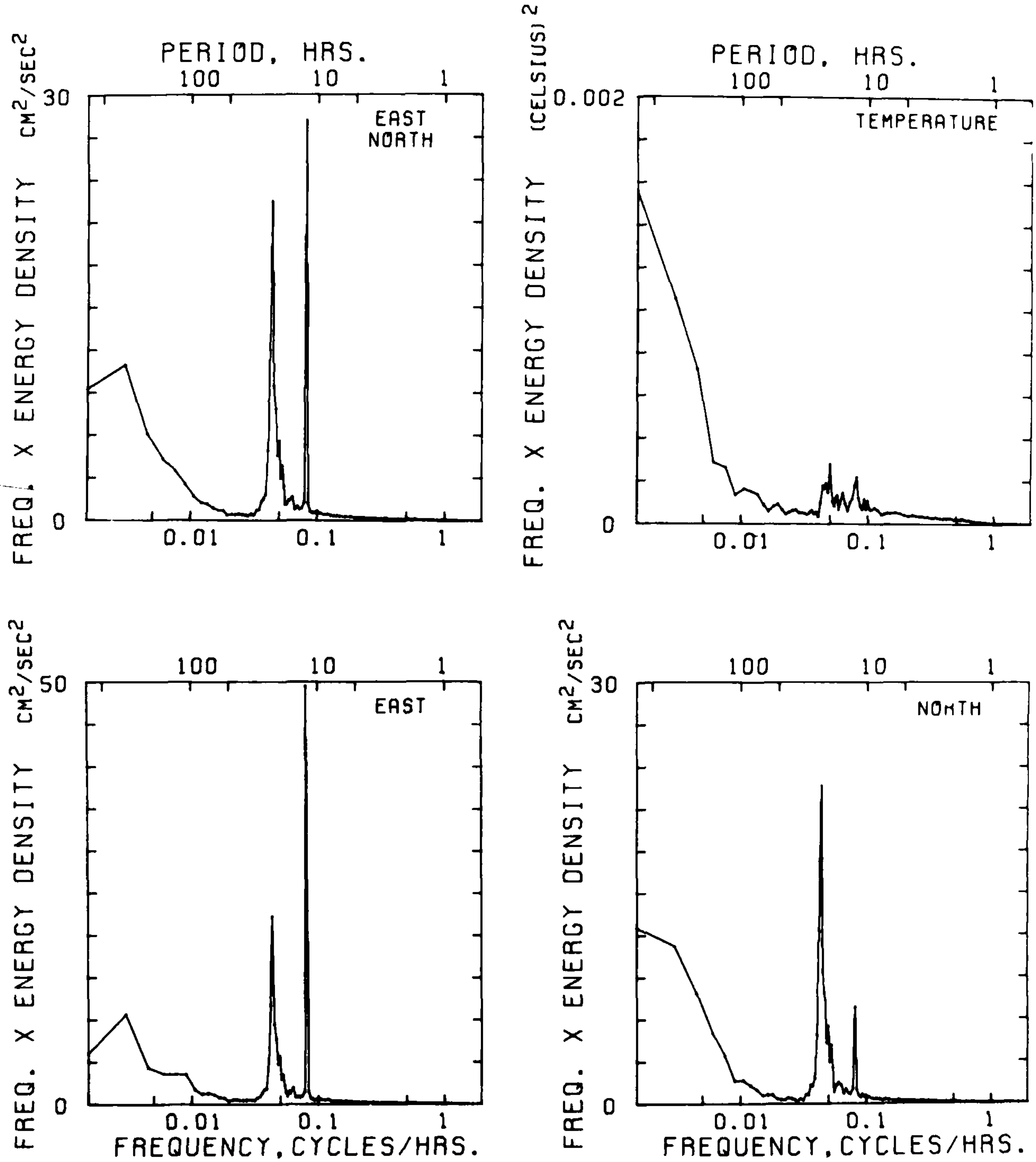


6181A1DGAU24
2002 M

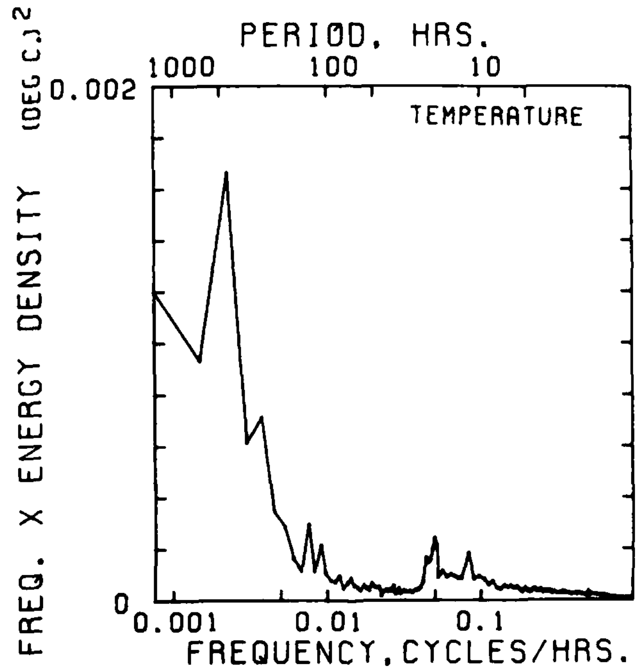


6201A1DGAU24
[illegible] M

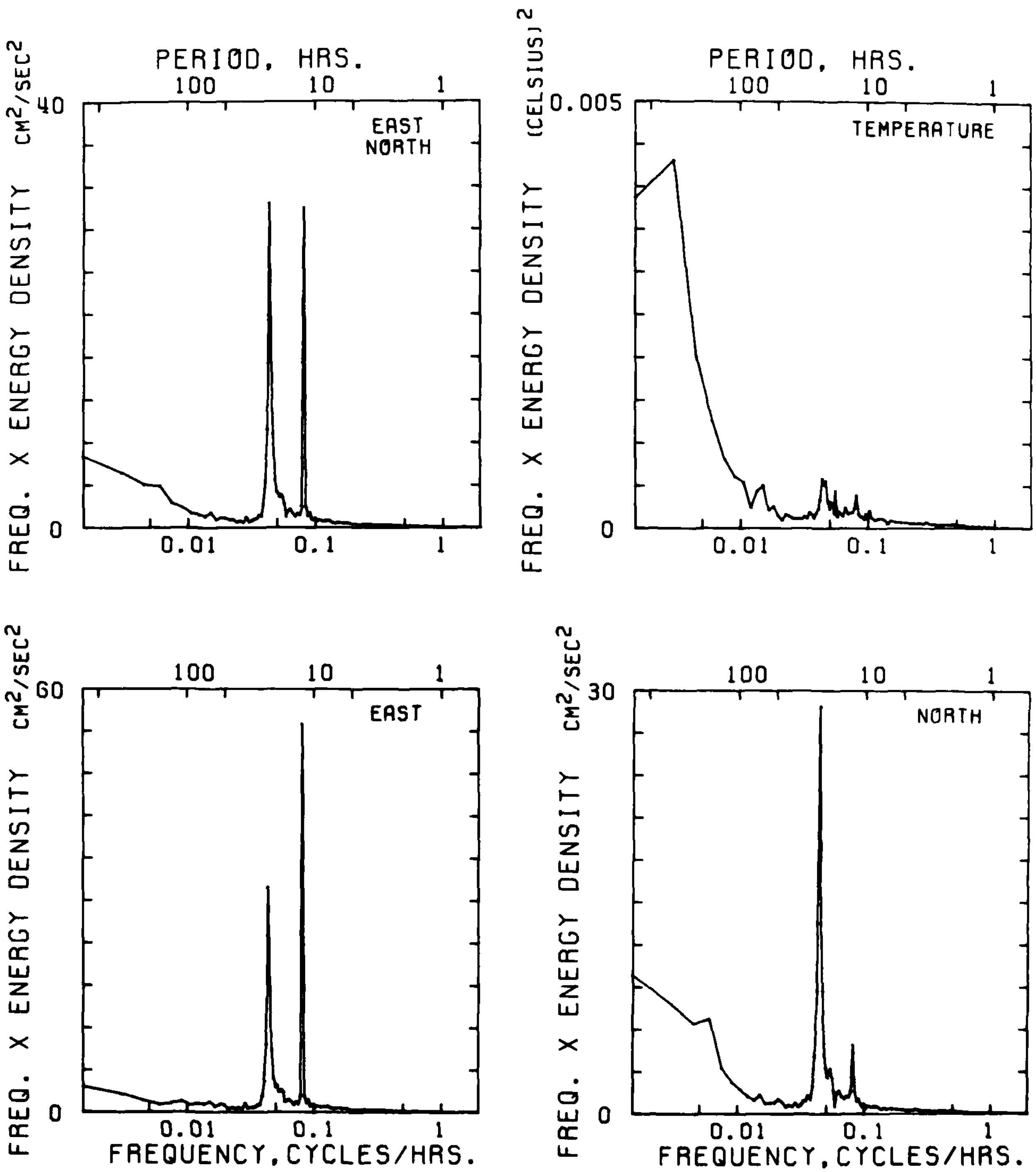
AUTO SPECTRUM
6161B900
1995 METERS
77-V-14 TO 78-IV-12
4 PIECES WITH 4000 ESTIMATES
PER PIECE. AVERAGED OVER
3 ADJACENT FREQUENCY BANDS



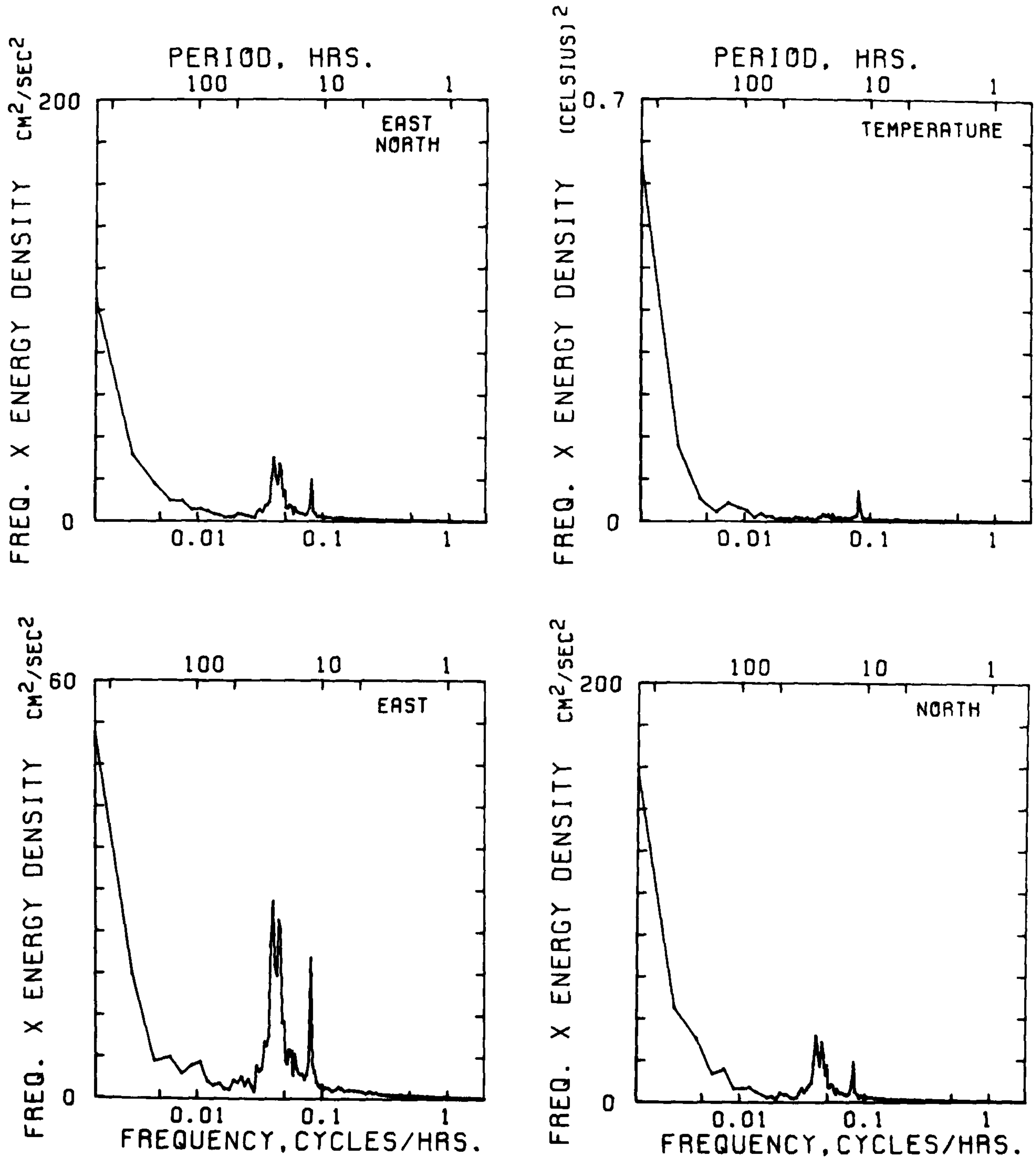
AUTO SPECTRUM
6162$1800
1983 METERS
77-V-15 TO 78-IV-13
2 PIECES WITH 4000 ESTIMATES
PER PIECE. AVERAGED OVER
3 ADJACENT FREQUENCY BANDS



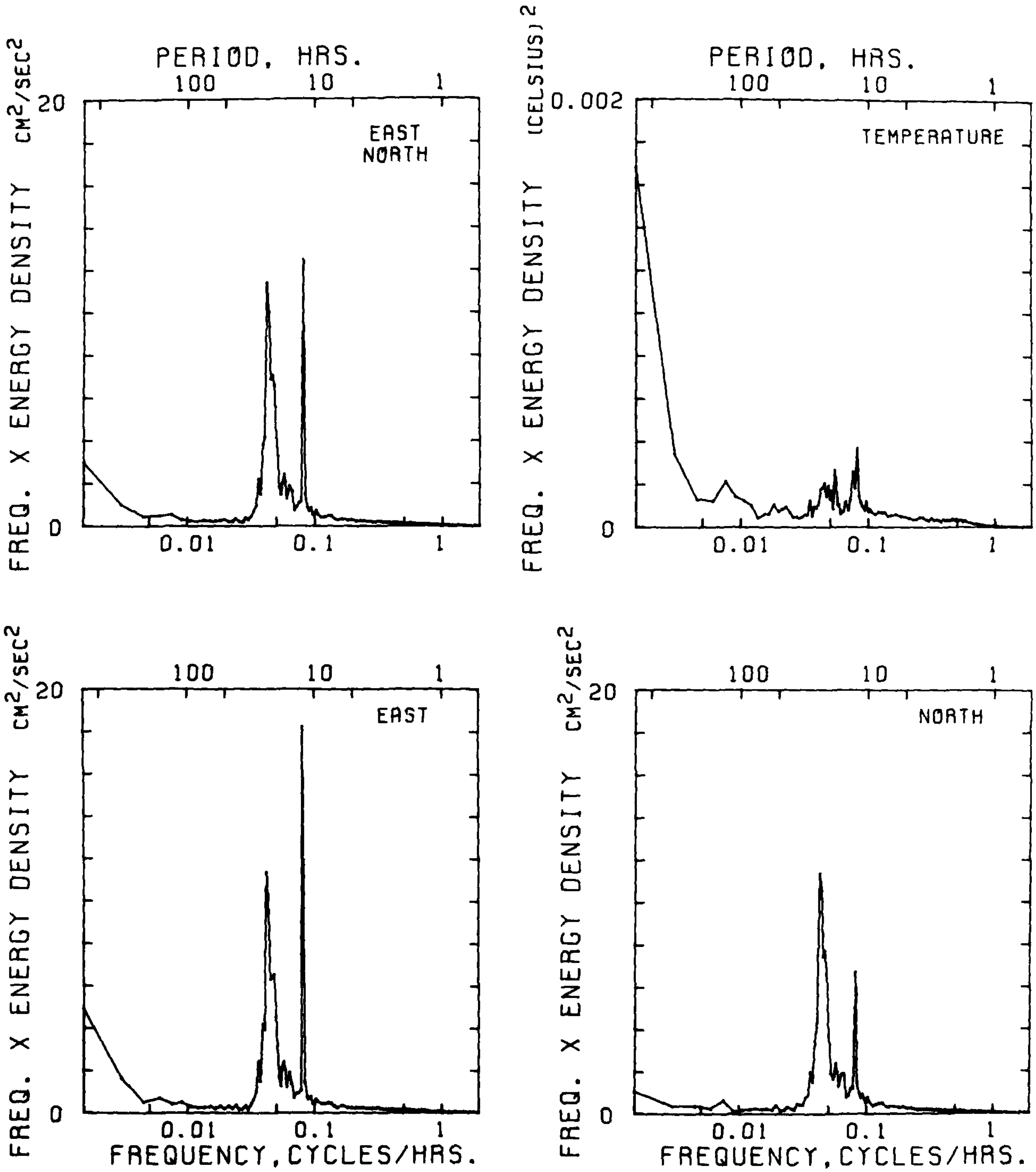
AUTO SPECTRUM
6163C900
2796 METERS
77-V-14 TO 78-IV-12
4 PIECES WITH 4000 ESTIMATES
PER PIECE. AVERAGED OVER
3 ADJACENT FREQUENCY BANDS



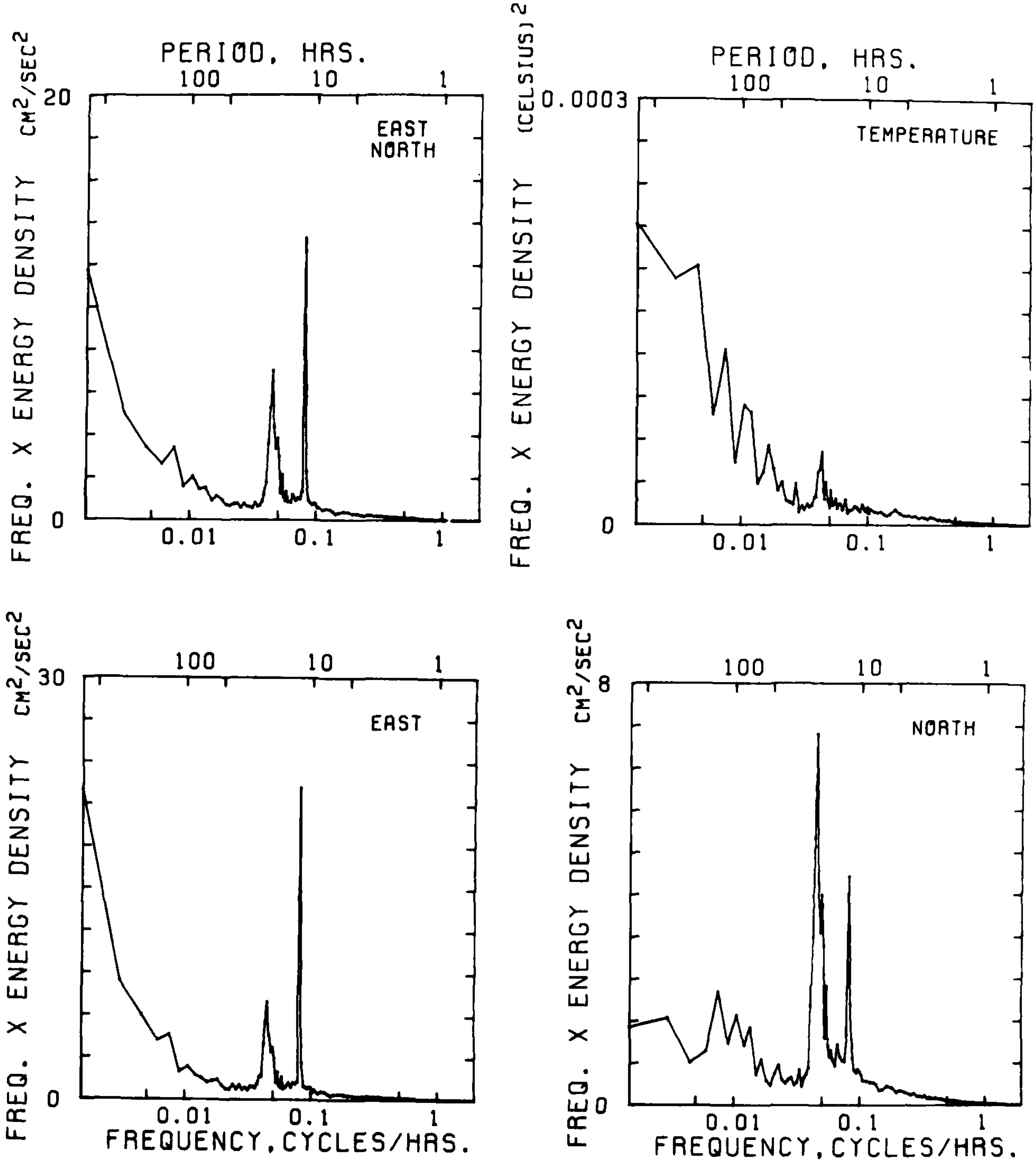
AUTO SPECTRUM
61718900
601 METERS
77-V-14 TO 78-IV-13
4 PIECES WITH 4000 ESTIMATES
PER PIECE. AVERAGED OVER
3 ADJACENT FREQUENCY BANDS



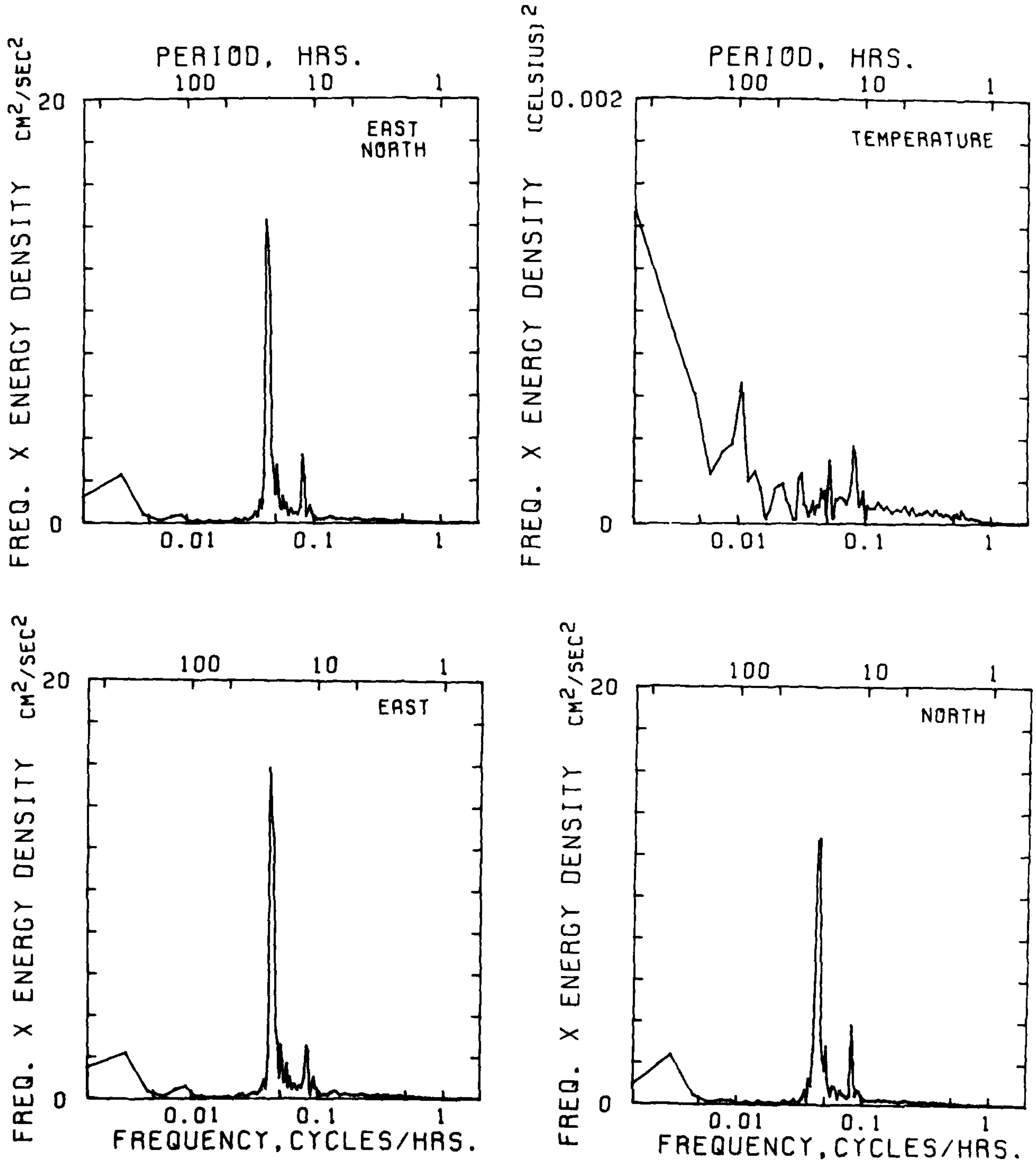
AUTO SPECTRUM
61720900
2002 METERS
77-V-15 TO 78-IV-13
4 PIECES WITH 4000 ESTIMATES
PER PIECE. AVERAGED OVER
3 ADJACENT FREQUENCY BANDS



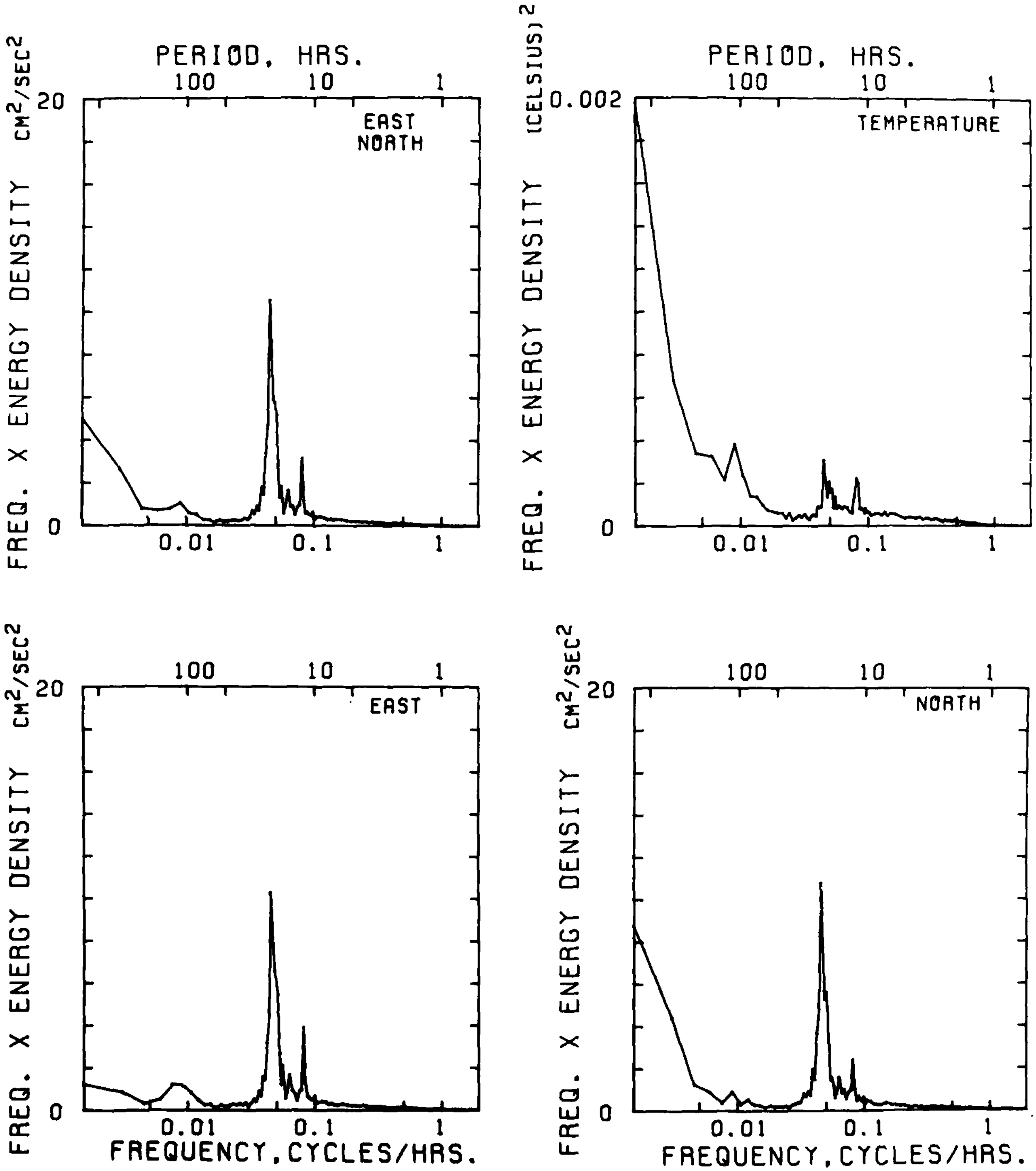
AUTO SPECTRUM
6173C900
3602 METERS
77-V-15 TO 78-IV-13
4 PIECES WITH 4000 ESTIMATES
PER PIECE. AVERAGED OVER
3 ADJACENT FREQUENCY BANDS



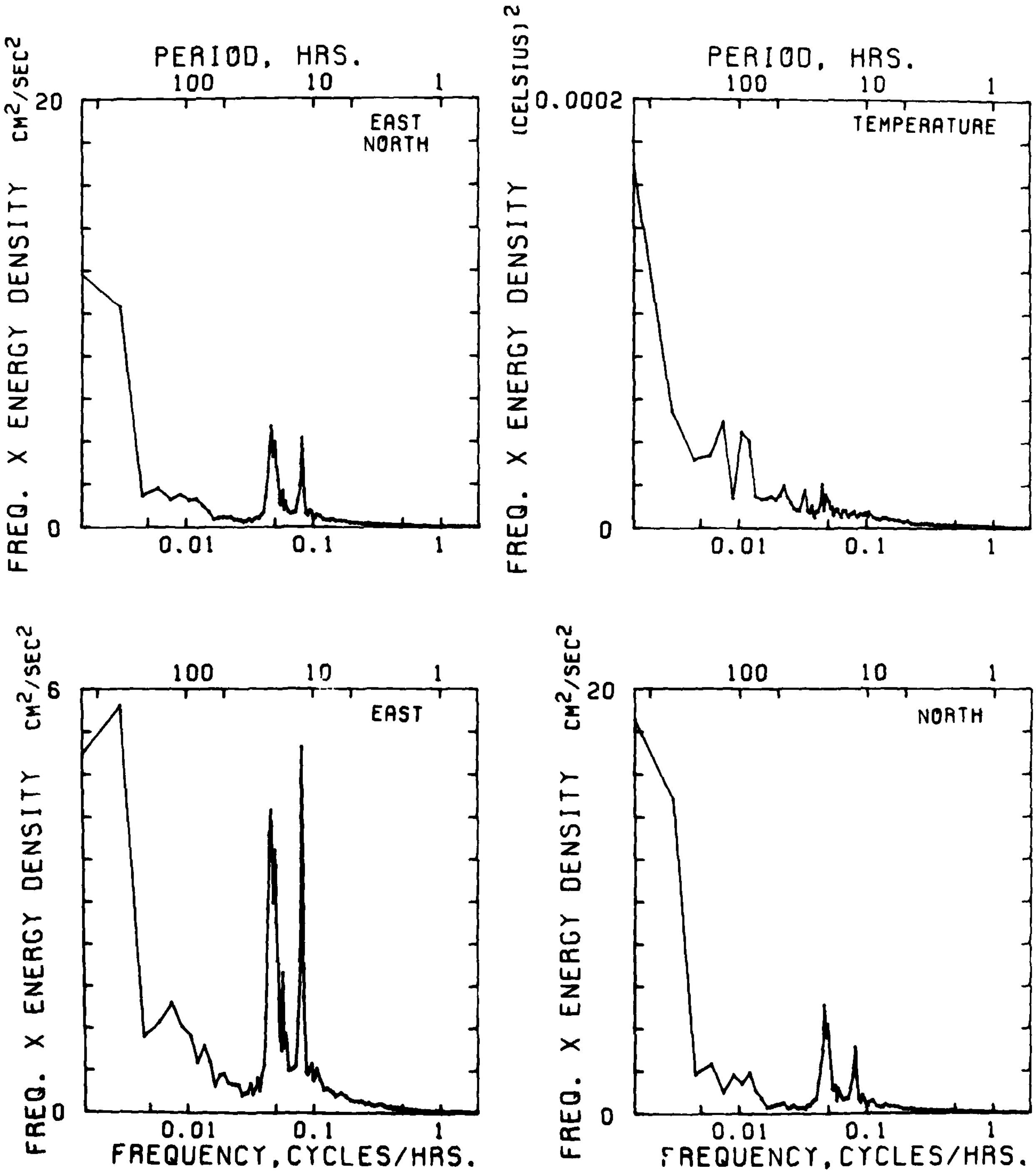
AUTO SPECTRUM
618109000
2002 METERS
77-V-15 TO 77-VIII-07
1 PIECES WITH 4000 ESTIMATES
PER PIECE. AVERAGED OVER
3 ADJACENT FREQUENCY BANDS



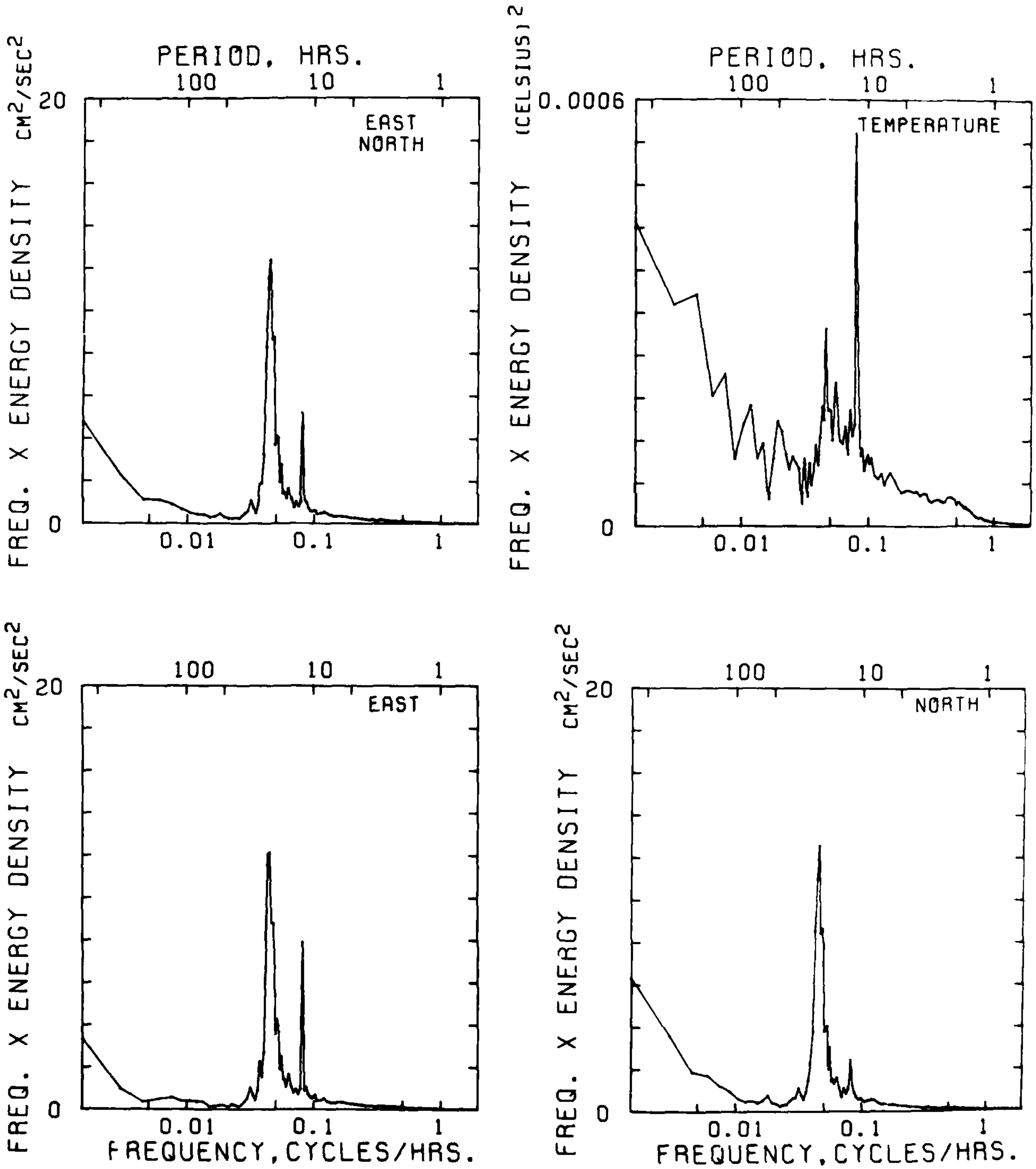
AUTO SPECTRUM
6182C900
3003 METERS
77-V-15 TO 78-IV-13
4 PIECES WITH 4000 ESTIMATES
PER PIECE. AVERAGED OVER
3 ADJACENT FREQUENCY BANDS



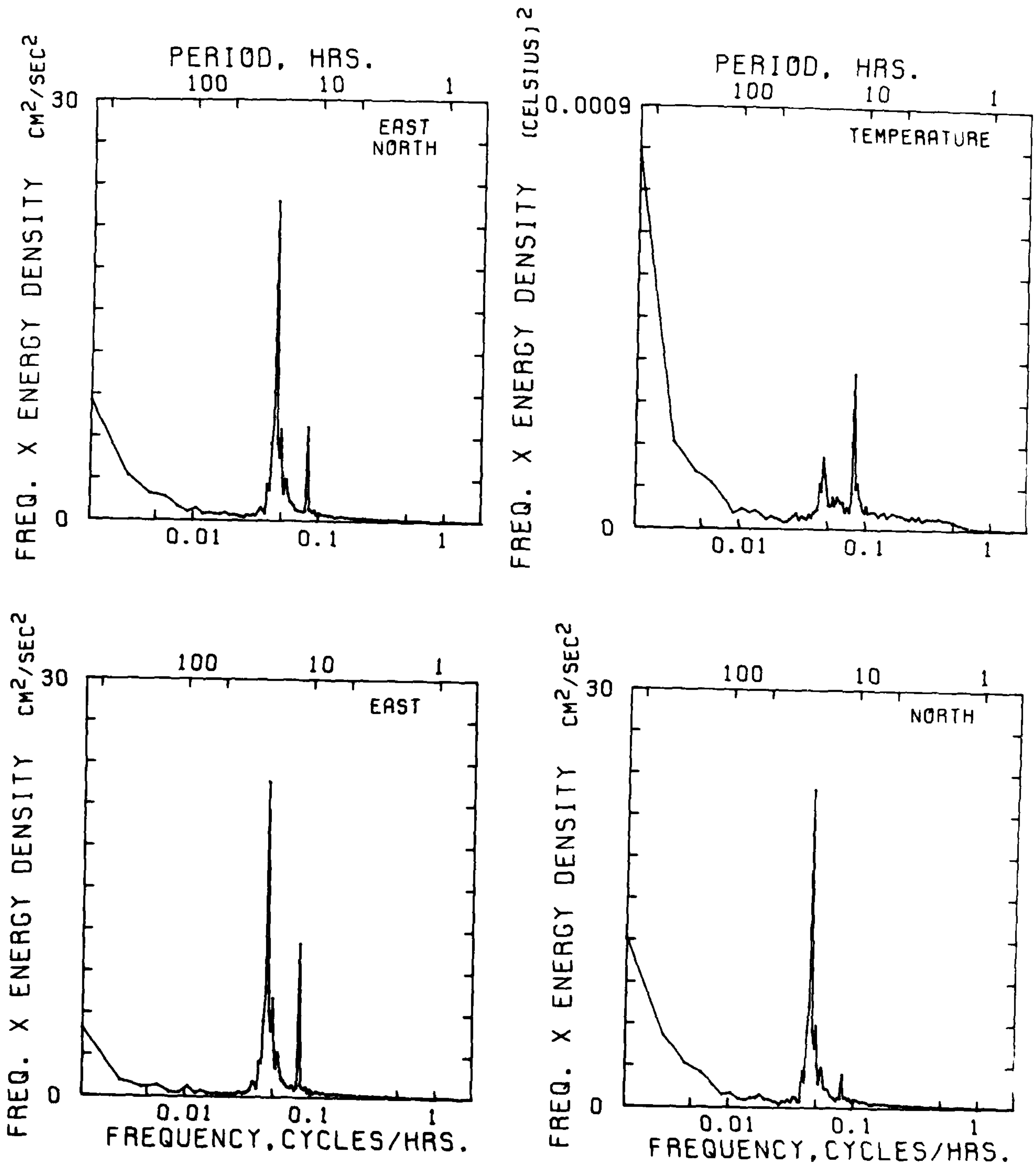
AUTO SPECTRUM
6183C900
3802 METERS
77-V-15 TO 78-IV-13
4 PIECES WITH 4000 ESTIMATES
PER PIECE. AVERAGED OVER
3 ADJACENT FREQUENCY BANDS



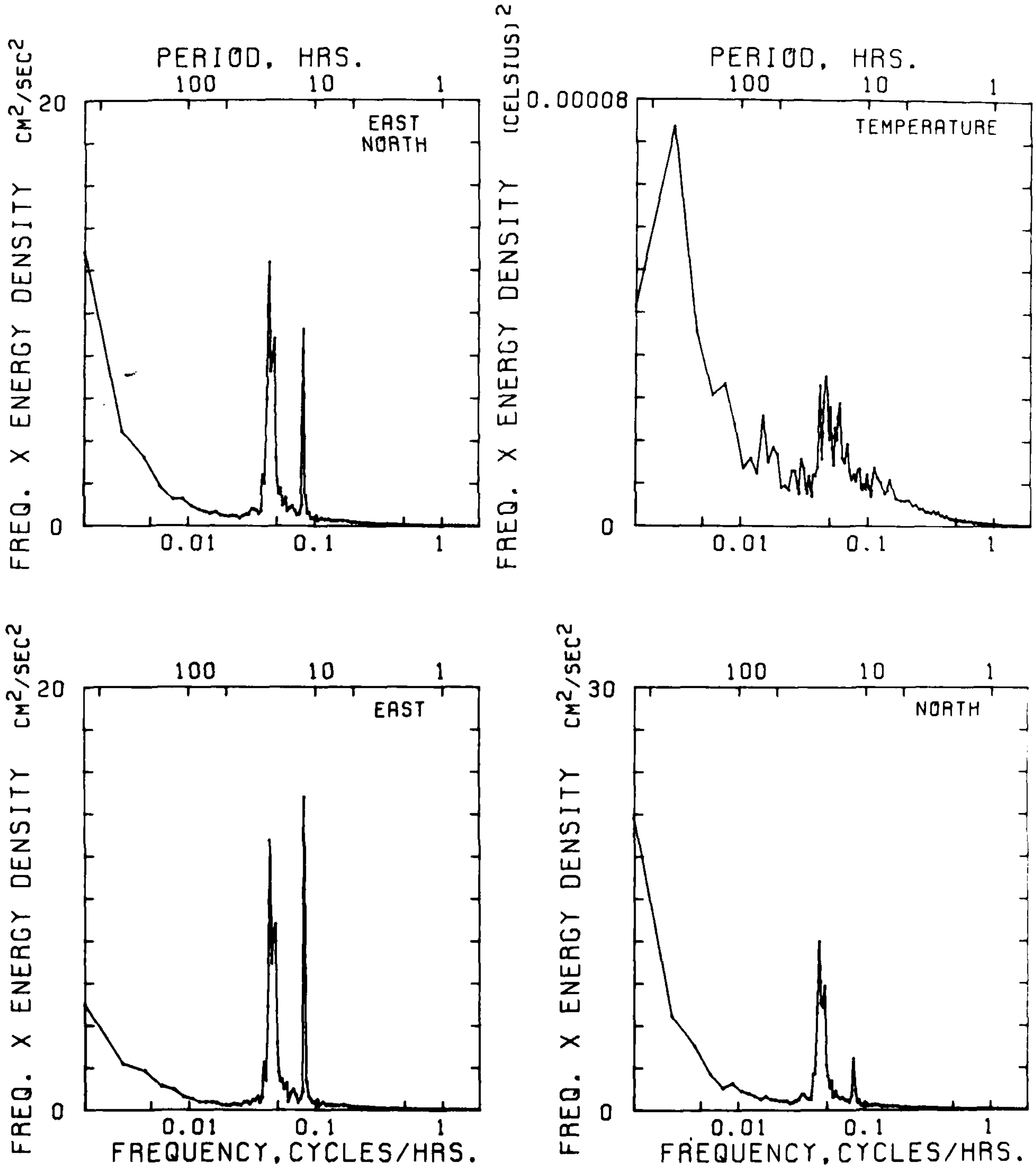
AUTO SPECTRUM
62018900
1958 METERS
77-V-16 TO 78-IV-14
4 PIECES WITH 4000 ESTIMATES
PER PIECE. AVERAGED OVER
3 ADJACENT FREQUENCY BANDS



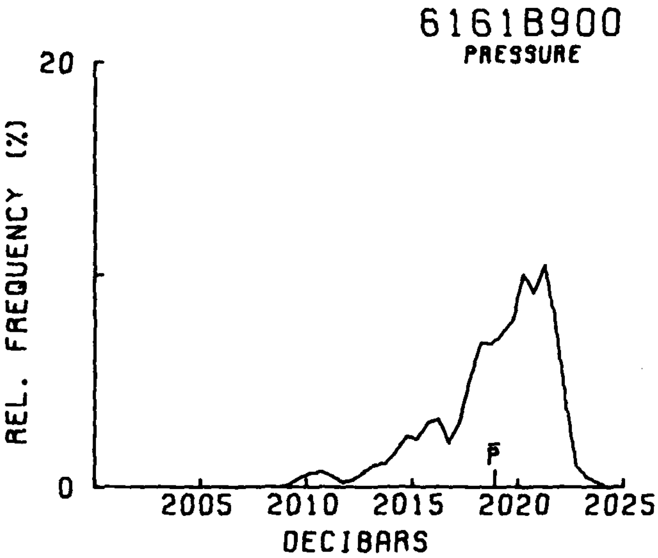
AUTO SPECTRUM
6202C900
2958 METERS
77-V-16 TO 78-IV-14
4 PIECES WITH 4000 ESTIMATES
PER PIECE. AVERAGED OVER
3 ADJACENT FREQUENCY BANDS

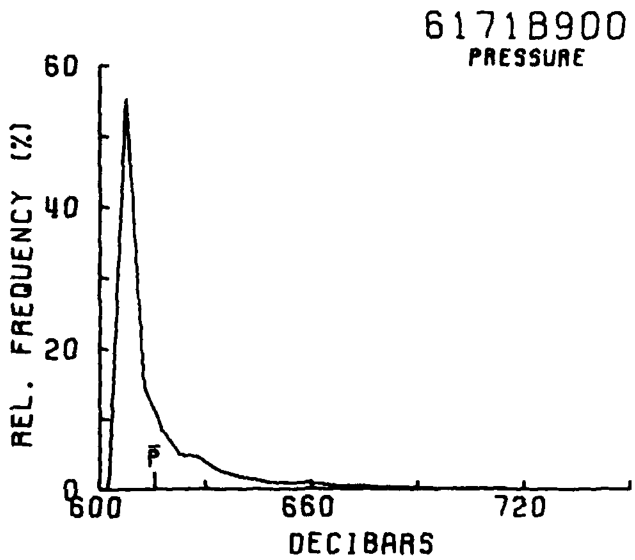


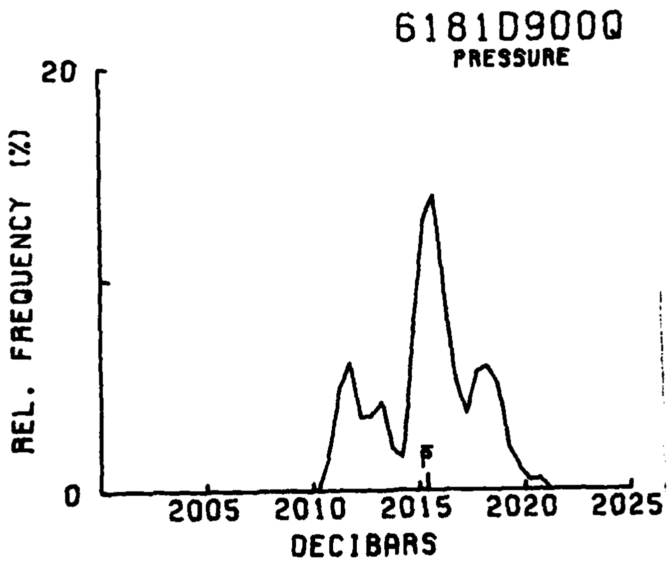
AUTO SPECTRUM
62030900
4987 METERS
77-V-16 TO 78-IV-14
4 PIECES WITH 4000 ESTIMATES
PER PIECE. AVERAGED OVER
3 ADJACENT FREQUENCY BANDS

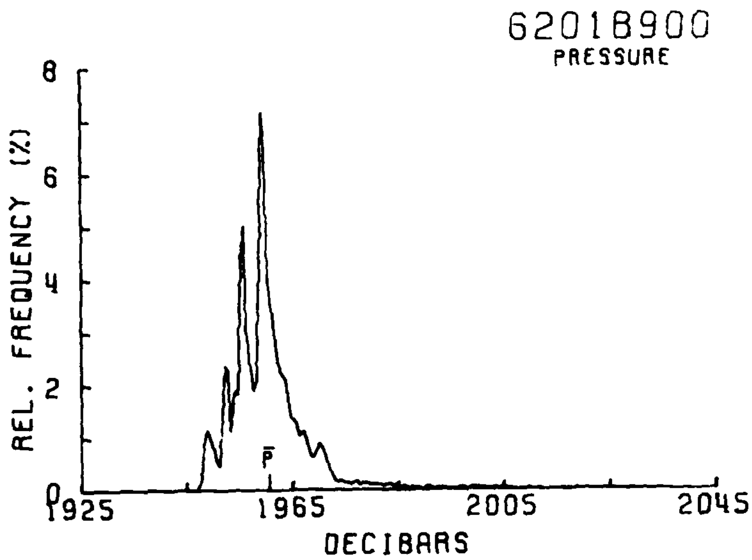


PRESSURE HISTOGRAMS MOORINGS 616, 617, 618, 620









STATISTICS AND HISTOGRAMS RECORD 6161

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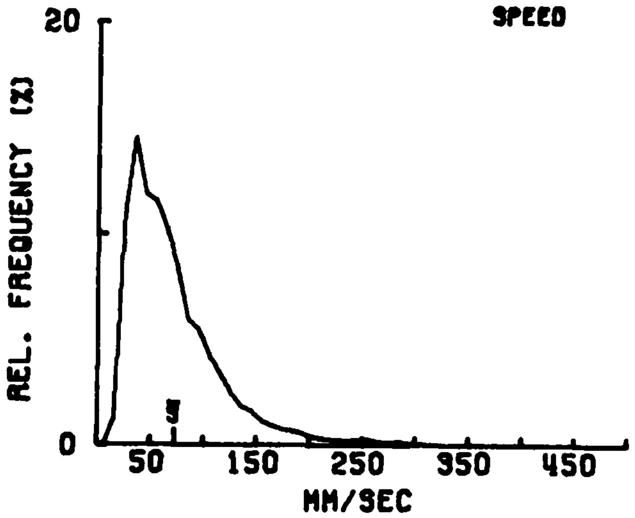
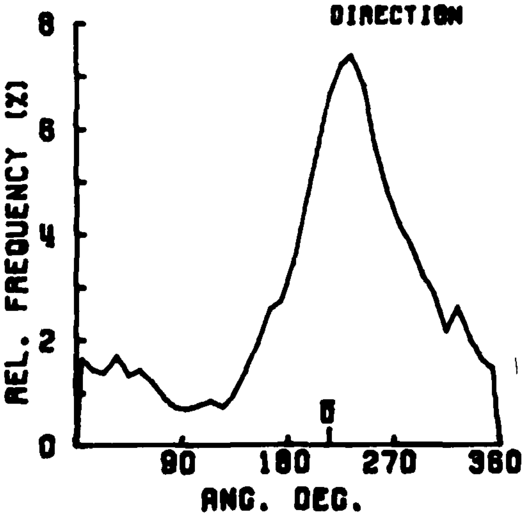
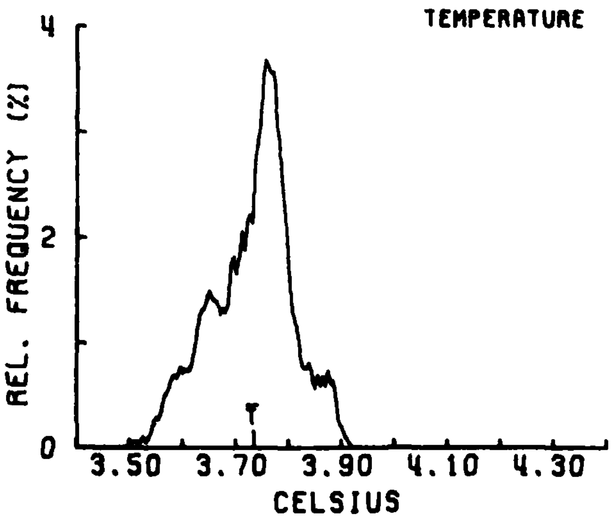
************************************************************************
** 6161B90C      ** 34208 POINTS  FROM 77-  V -14  TO 78-  V -05
INST. V-326P   DEPTH 1995 M.   UNITS = MM/SEC , DEGREES CELSIUS
VARIABLE ------- EAST ------ NORTH ----- SPEED ---- TEMPERATURE
MEAN       =    -28.795      -19.181       71.411        3.733
STD.ERR.   =       .281         .308         .244         .414E-3
VARIANCE   =   2697.541     3239.451     2034.467         .587E-2
KURTOSIS   =      6.522        4.504        6.768        2.787
SKEWNESS   =    -.523E-1      -.274        1.709        -.302
MINIMUM    =   -297.775     -259.468        4.051        3.490
MAXIMUM    =    238.928      209.669      314.576        3.918
-----EAST & NORTH-------- * * * * * * * * * * * * * * * * * * *
COVARIANCE    =    585.342   *
CORR. COEF.   =       .198   *
ORIENTATION   =     32.580   *
MAJAX         =     60.112   *
MINAX         =     48.203   *
ELLIP         =       .198   *
************************************************************************
VARIABLE   *    PRESSURE
UNITS      *    DECIBARS
************************
MEAN        =    2018.909
STD. ERR.   =       .145E-1
VARIANCE    =       7.226
STD. DEV.   =       2.688
KURTOSIS    =       2.711
SKEWNESS    =      -1.126
MINIMUM     =    2009.183
MAXIMUM     =    2024.062
```







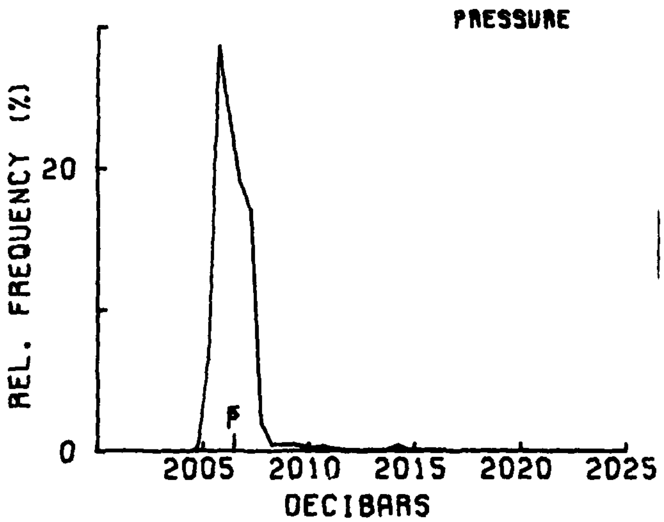
STATISTICS AND HISTOGRAMS RECORD 6162

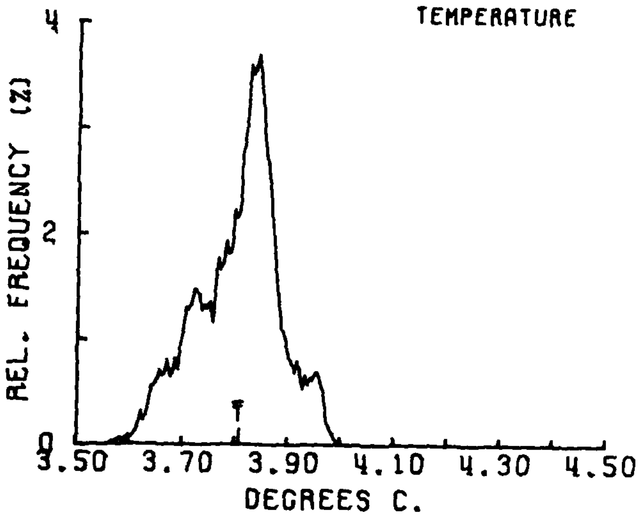
VARIABLE	TEMPERATURE	PRESSURE
UNITS	DEGREES C.	DECIBARS
MEAN =	3.807	2006.490
STD. ERR. =	.593E-3	.855E-2
VARIANCE =	.599E-2	1.246
STD. DEV. =	.774E-1	1.116
KURTOSIS =	2.787	34.091
SKEWNESS =	-.302	4.274
MINIMUM =	3.563	2004.815
MAXIMUM =	3.992	2018.201

* SAMPLE SIZE = 17064 POINTS

* SPANNING RANGE
* FROM 77- V -15 04.45.00
* TO 78- V -05 16.15.00

* DURATION 355.48 DAYS





STATISTICS AND HISTOGRAMS RECORD 6163

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********************************************************************
** 6163C900      ** 34192 POINTS  FROM 77-  V -14  TO 78-  V -05
INST. V-C101   DEPTH 2796 M.   UNITS = MM/SEC , DEGREES CELSIUS
VARIABLE ------- EAST ------ NORTH ----- SPEED ---- TEMPERATURE
MEAN       =   -37.552      -64.734      92.142        2.705
STD.ERR.   =      .223         .311        .249         .680E-3
VARIANCE   =  1701.922     3307.711    2120.078         .158E-1
KURTOSIS   =     2.998        2.719       2.519        2.900
SKEWNESS   =      .164         .301        .462         .191
MINIMUM    =  -177.707     -214.214      13.374        2.365
MAXIMUM    =   125.488      121.826     242.418        3.148
-----EAST & NORTH-------- * * * * * * * * * * * * * * * * * * * *
COVARIANCE  =  1181.517   *
CORR. COEF. =      .498   *
ORIENTATION =    27.901   *
MAJAX       =    62.716   *
MINAX       =    32.807   *
ELLIP       =      .477   *
********************************************************************
```
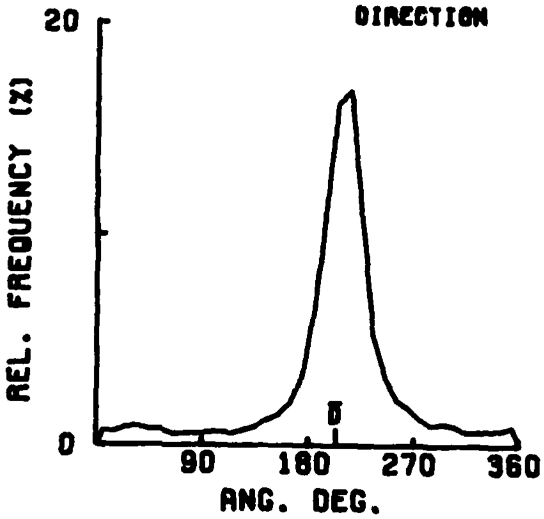
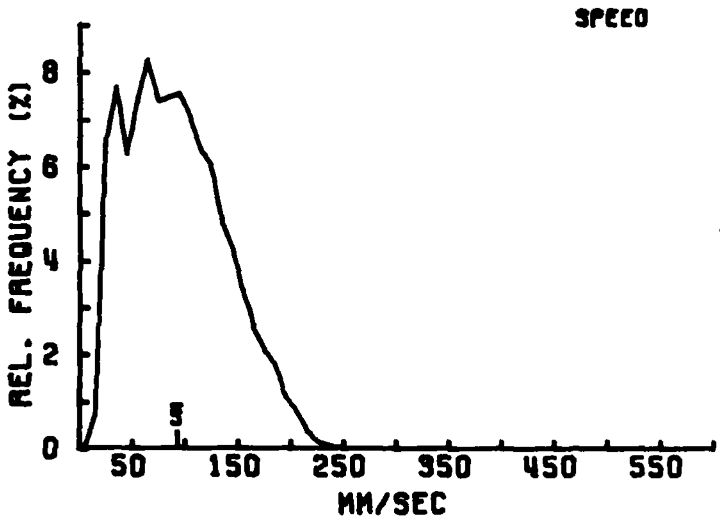
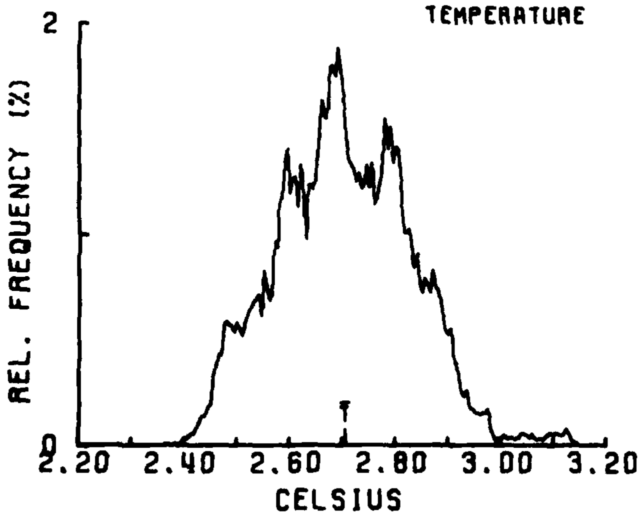







STATISTICS AND HISTOGRAMS RECORD 6171

** 6171B900 ** 34188 POINTS FROM 77- V -14 TO 78- V -05

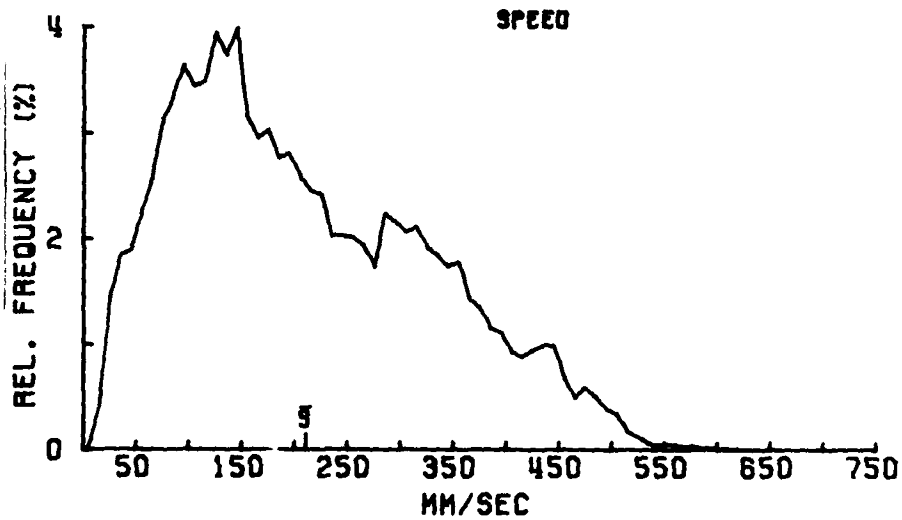
INST. V-201P DEPTH 601 M. UNITS = MM/SEC , DEGREES CELSIUS

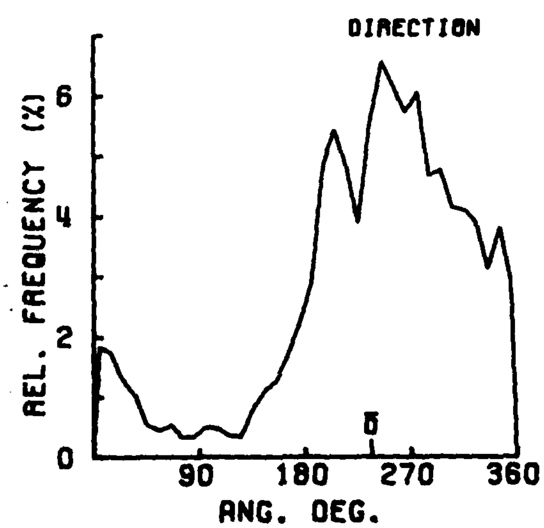
VARIABLE		EAST	NORTH	SPEED	TEMPERATURE
MEAN	=	-103.630	-20.275	209.798	15.072
STD.ERR.	=	.640	.987	.650	.727E-2
VARIANCE	=	14007.820	33322.682	14465.355	1.605
KURTOSIS	=	3.728	3.296	2.444	4.670
SKEWNESS	=	.139	.967E-1	.547	-.583
MINIMUM	=	-458.779	-603.521	4.055	9.769
MAXIMUM	=	368.026	514.503	617.144	18.135

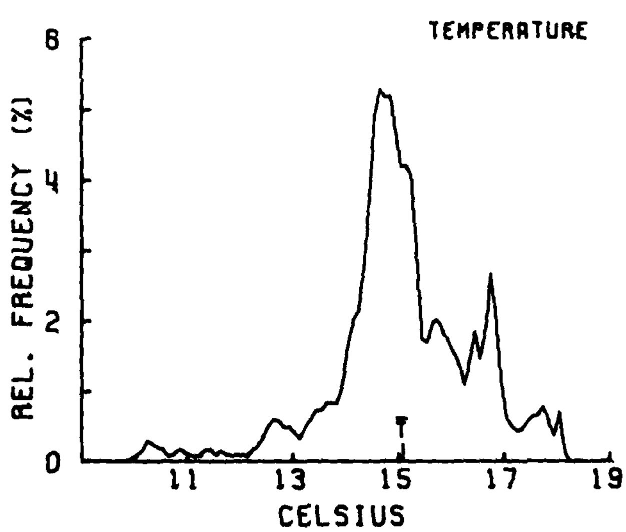
-----EAST & NORTH--------

COVARIANCE	=	-3119.464
CORR. COEF.	=	-.144
ORIENTATION	=	171.049
MAJAX	=	183.886
MINAX	=	116.261
ELLIP	=	.368

VARIABLE		PRESSURE
UNITS		DECIBARS
MEAN	=	615.531
STD. ERR.	=	.812E-1
VARIANCE	=	225.197
STD. DEV.	=	15.007
KURTOSIS	=	12.714
SKEWNESS	=	2.813
MINIMUM	=	605.903
MAXIMUM	=	723.315







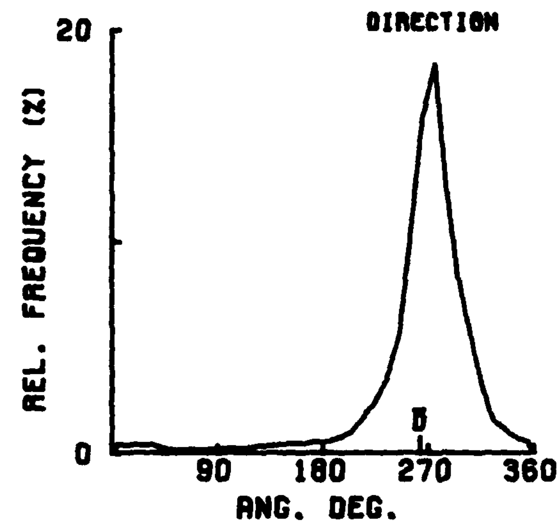
STATISTICS AND HISTOGRAMS RECORD 6172

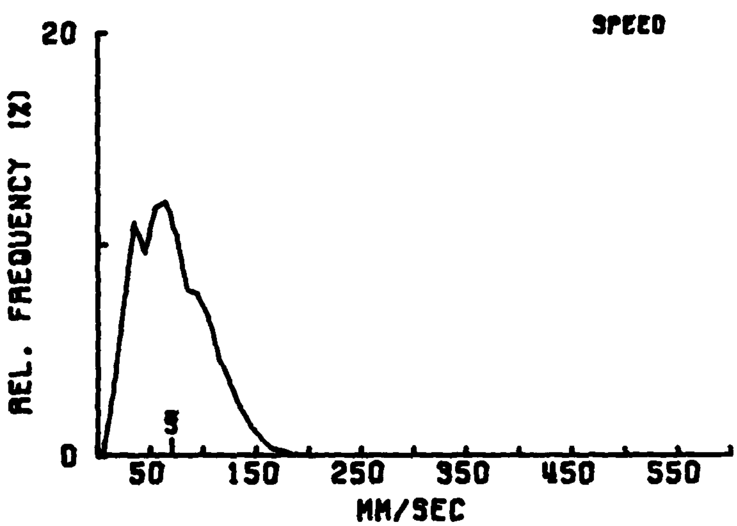
** 6172D900 ** 34178 POINTS FROM 77- V -15 TO 78- V -06

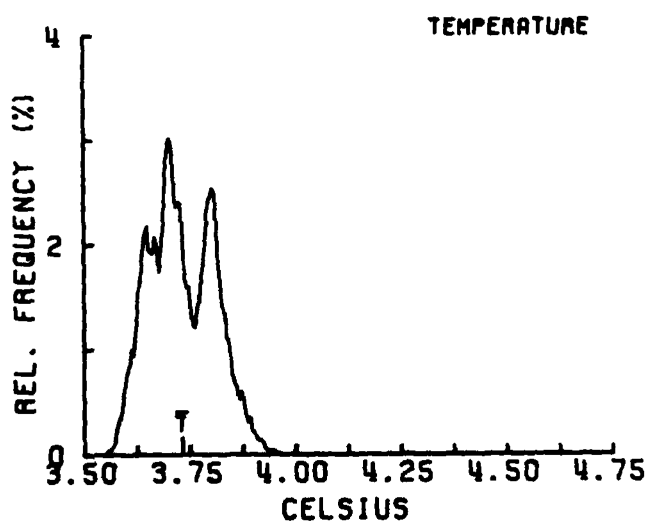
INST. V-5101 DEPTH 2002 M. UNITS = MM/SEC , DEGREES CELSIUS

VARIABLE	EAST	NORTH	SPEED	TEMPERATURE
MEAN =	-61.332	1.565	70.196	3.731
STD.ERR. =	.213	.143	.178	.412E-3
VARIANCE =	1544.264	698.084	1078.947	.579E-2
KURTOSIS =	3.226	3.556	2.776	2.260
SKEWNESS =	.487E-1	-.227	.553	.185
MINIMUM =	-215.314	-123.183	3.056	3.551
MAXIMUM =	95.797	113.611	215.401	3.965

-----EAST & NORTH--------	
COVARIANCE =	-71.804
CORR. COEF. =	-.692E-1
ORIENTATION =	94.816
MAJAX =	39.374
MINAX =	26.307
ELLIP =	.332







STATISTICS AND HISTOGRAMS RECORD 6173

****

** 6173C900 ** 34161 POINTS FROM 77- V -15 TO 78- V -06

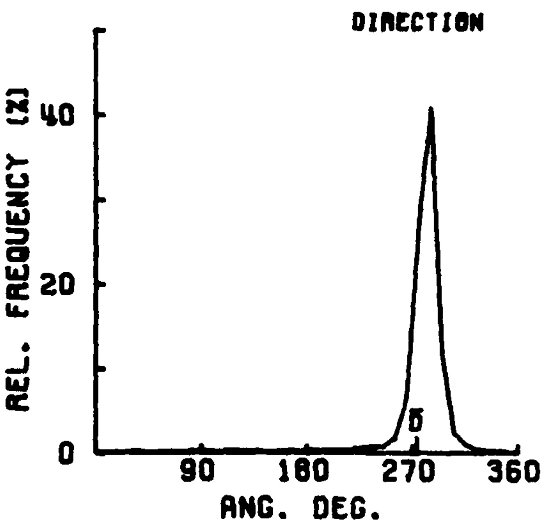
INST. V-5102 DEPTH 3602 M. UNITS = MM/SEC , DEGREES CELSIUS

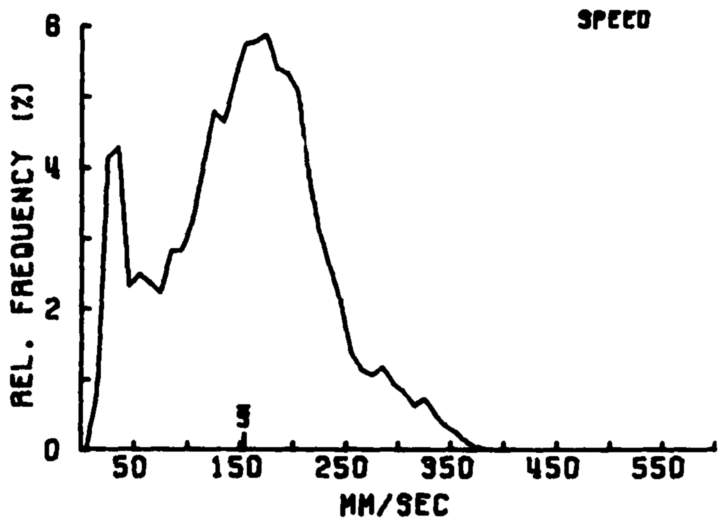
VARIABLE		EAST	NORTH	SPEED	TEMPERATURE
MEAN	=	-145.897	30.932	153.643	2.209
STD.ERR.	=	.421	.154	.401	.131E-3
VARIANCE	=	6045.022	808.988	5490.645	.535E-3
KURTOSIS	=	2.897	3.045	2.661	5.650
SKEWNESS	=	.109	-.552E-1	.145	1.038
MINIMUM	=	-367.696	-87.920	18.410	2.149
MAXIMUM	=	76.809	132.477	372.719	2.335

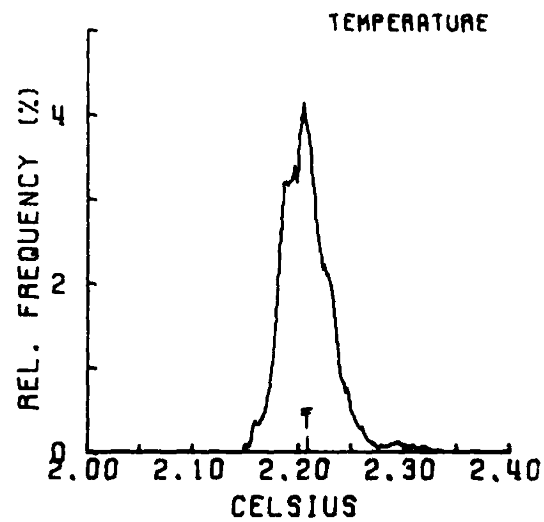
-----EAST & NORTH--------- * * * * * * * * * * * * * * * * * * *

COVARIANCE	=	-1301.566
CORR. COEF.	=	-.589
ORIENTATION	=	103.217
MAJAX	=	79.691
MINAX	=	22.434
ELLIP	=	.718

****







STATISTICS AND HISTOGRAMS RECORD 6181

****

** 6181D90C ** 33358 POINTS FROM 77- V -15 TO 78- V -03
INST. V-C110P DEPTH 2002 M. UNITS = MM/SEC , DEGREES CELSIUS

VARIABLE		EAST	NORTH	SPEED	TEMPERATURE
MEAN	=	-5.351	-49.640	61.011	3.743
STD.ERR.	=	.143	.203	.159	.387E-3
VARIANCE	=	689.197	1393.027	852.636	.506E-2
KURTOSIS	=	3.043	3.720	4.184	2.621
SKEWNESS	=	.329	-.205	1.039	.233
MINIMUM	=	-105.812	-202.471	18.202	3.547
MAXIMUM	=	96.621	78.457	203.293	3.952

-----EAST & NORTH--------

COVARIANCE	=	-145.533
CORR. COEF.	=	-.149
ORIENTATION	=	168.766
MAJAX	=	37.709
MINAX	=	25.696
ELLIP	=	.319

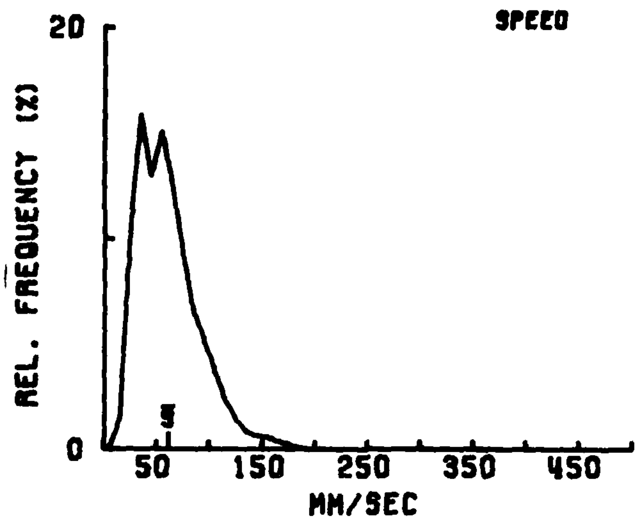
****

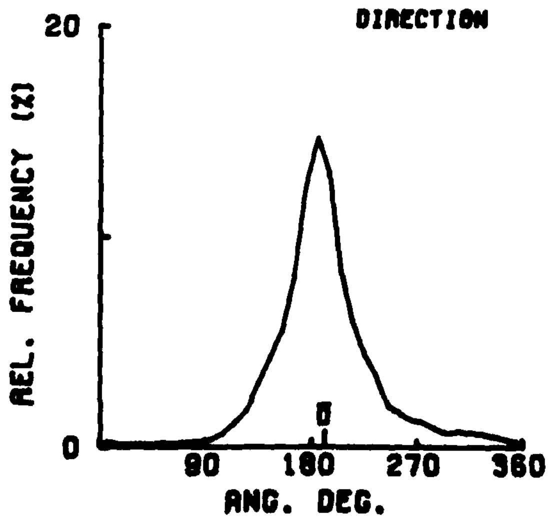
VARIABLE	*	PRESSURE
UNITS	*	DECIBARS
MEAN	=	2015.397
STD. ERR.	=	.222E-1
VARIANCE	=	5.295
STD. DEV.	=	2.301
KURTOSIS	=	2.488
SKEWNESS	=	-.195
MINIMUM	=	2010.712
MAXIMUM	=	2020.951

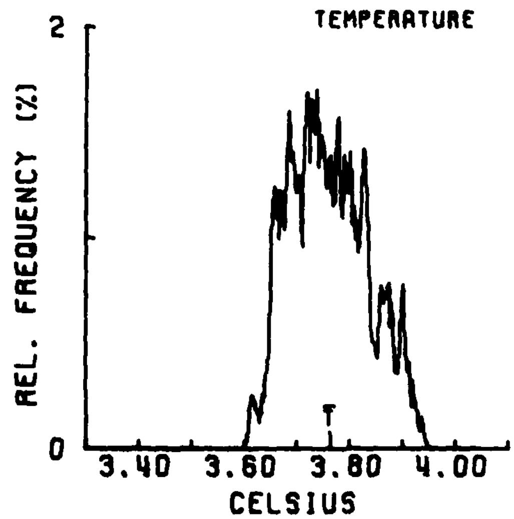
NOTE: PRESSURE RECORD ONLY
SAMPLE SIZE = 10792 POINTS

SPANNING RANGE:

FROM 77-05-15
TO 77-09-05
DURATION: 112 DAYS

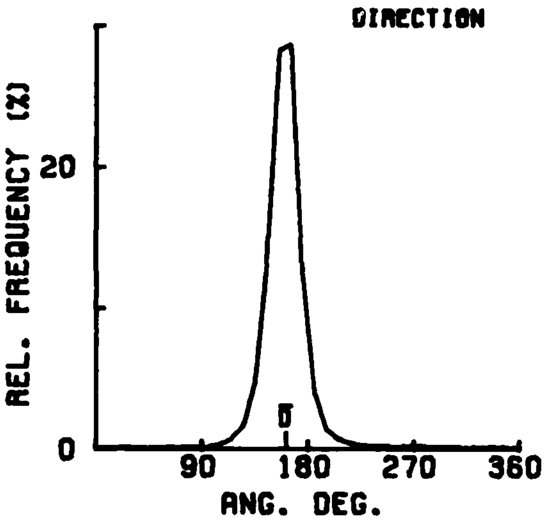


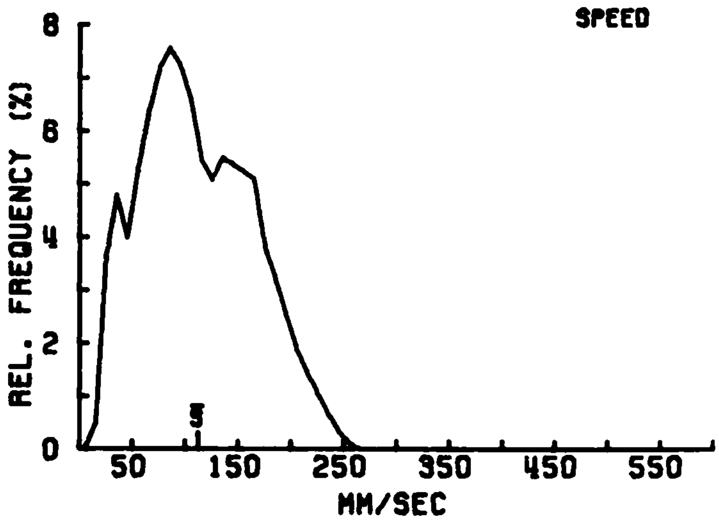


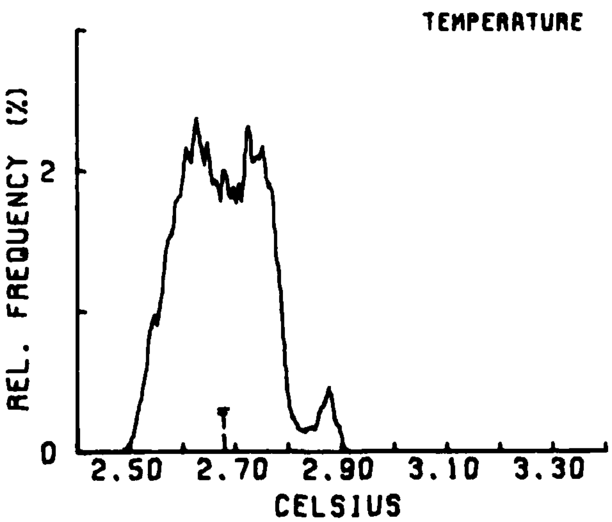


STATISTICS AND HISTOGRAMS RECORD 6182

```
****************************************************************
** 6182C900      ** 33888 POINTS   FROM 77-  V -15  TO 78-  V -03
INST. V-0431    DEPTH 3003 M.    UNITS = MM/SEC , DEGREES CELSIUS
VARIABLE ------- EAST ------ NORTH ----- SPEED ---- TEMPERATURE
MEAN       =     36.728     -101.001      111.334        2.676
STD.ERR.   =       .150         .289         .285        .440E-3
VARIANCE   =    762.658     2828.849     2746.378        .655E-2
KURTOSIS   =      3.213        2.569        2.304        2.599
SKEWNESS   =     -.816E-1      -.140         .305         .251
MINIMUM    =    -82.983     -246.849       17.173        2.492
MAXIMUM    =    134.068       60.732      261.723        2.916
-----EAST & NORTH-------- * * * * * * * * * * * * * * * * * * *
COVARIANCE  =  -798.621    *
CORR. COEF. =     -.544    *
ORIENTATION =   161.147    *
MAJAX       =    55.691    *
MINAX       =    22.135    *
ELLIP       =      .603    *
****************************************************************
```







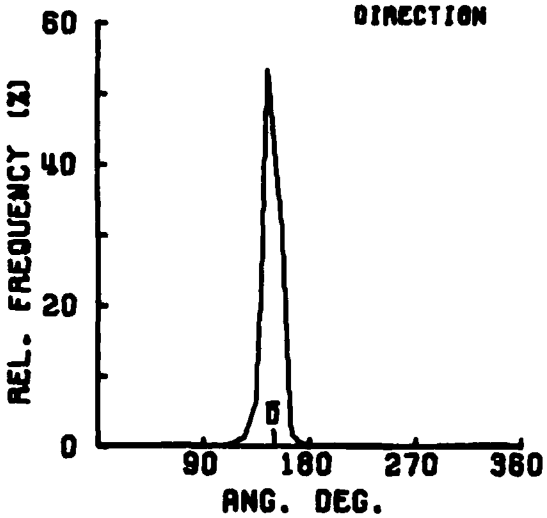
STATISTICS AND HISTOGRAMS RECORD 6183

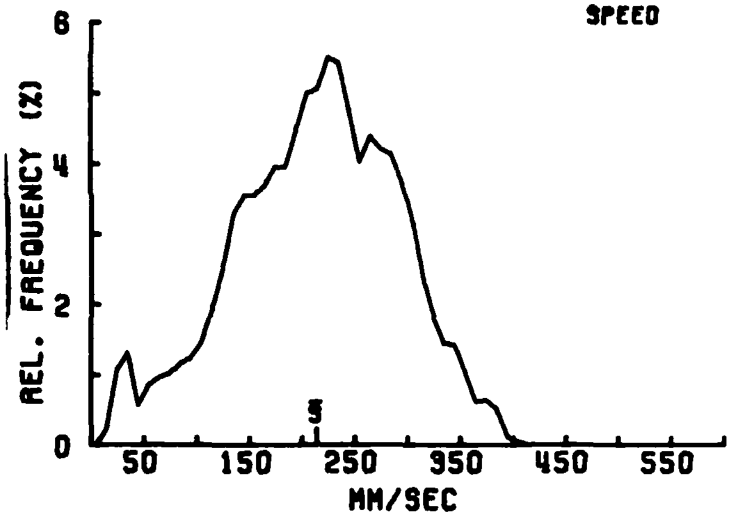
** 6183C90C ** 33880 POINTS FROM 77- V -15 TO 78- V -03
INST. V-0105 DEPTH 3802 M. UNITS = MM/SEC , DEGREES CELSIUS

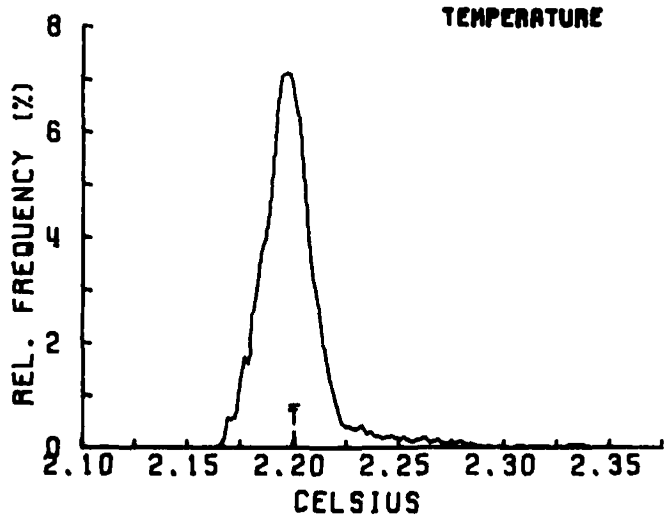
VARIABLE	EAST	NORTH	SPEED	TEMPERATURE
MEAN =	110.583	-179.278	213.544	2.200
STD.ERR. =	.230	.403	.423	.995E-4
VARIANCE =	1798.171	5492.220	6058.723	.336E-3
KURTOSIS =	4.163	3.428	2.694	15.532
SKEWNESS =	-.842	.450	-.256	2.631
MINIMUM =	-84.861	-372.212	20.000	2.165
MAXIMUM =	222.956	89.094	419.299	2.343

-----EAST & NORTH--------

COVARIANCE =	-2715.564
CORR. COEF. =	-.864
ORIENTATION =	152.111
MAJAX =	83.243
MINAX =	19.001
ELLIP =	.772

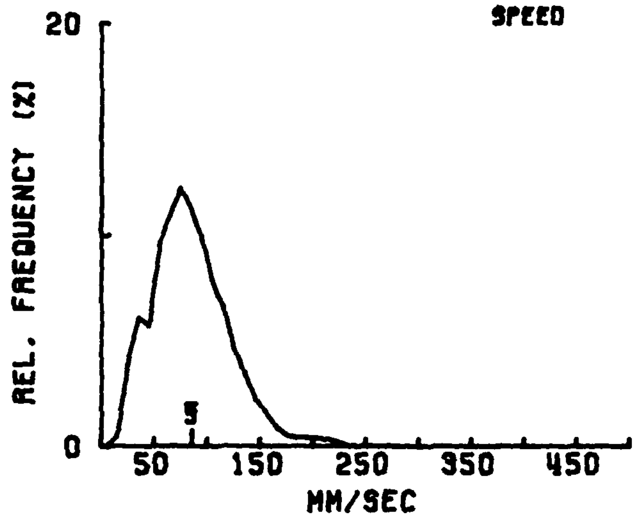


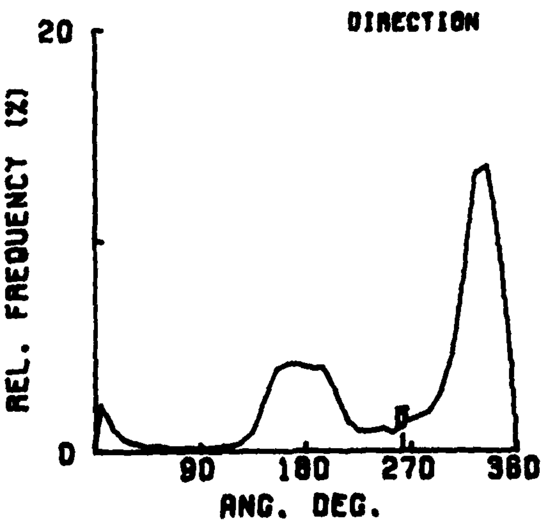


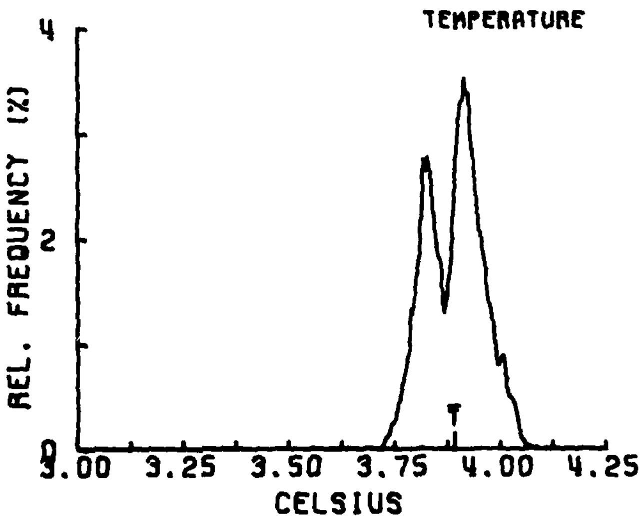


STATISTICS AND HISTOGRAMS RECORD 6201

```
*****************************************************************
** 62018900      ** 33698 POINTS  FROM 77-  V -16  TO 78-  V -02
INST. V-120P   DEPTH 1958 M.   UNITS = MM/SEC , DEGREES CELSIUS
VARIABLE ------- EAST ------ NORTH ----- SPEED ---- TEMPERATURE
MEAN        =   -28.890       26.662       84.601       3.890
STD.ERR.    =      .214         .400         .198        .364E-3
VARIANCE    =  1539.970     5390.110     1318.228        .446E-2
KURTOSIS    =     3.502        2.078        3.862       2.352
SKEWNESS    =      .986E-1     -.365         .739        .197E-1
MINIMUM     =  -189.910     -196.973       13.259       3.718
MAXIMUM     =   127.802      215.931      238.203       4.109
-----EAST & NORTH-------- * * * * * * * * * * * * * * * * * * *
COVARIANCE  = -1645.401   *
CORR. COEF. =     -.571   *
ORIENTATION =   159.739   *
MAJAX       =    77.443   *
MINAX       =    30.539   *
ELLIP       =      .606   *
*****************************************************************
VARIABLE  *    PRESSURE
UNITS     *    DECIBARS
**************************
MEAN        =    1960.297
STD. ERR.   =        .416E-1
VARIANCE    =      58.353
STD. DEV.   =       7.639
KURTOSIS    =      14.715
SKEWNESS    =       2.431
MINIMUM     =    1947.400
MAXIMUM     =    2029.250
```

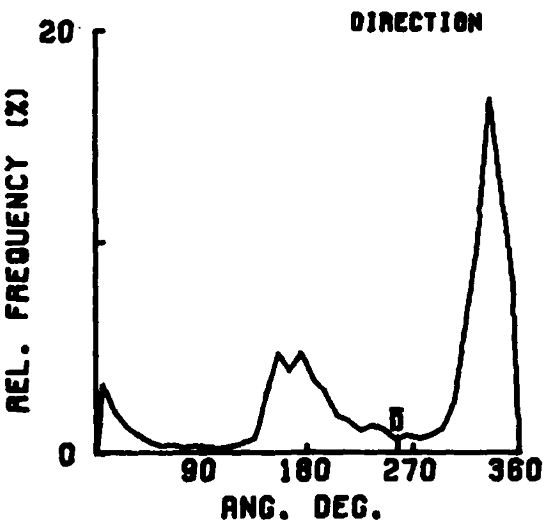


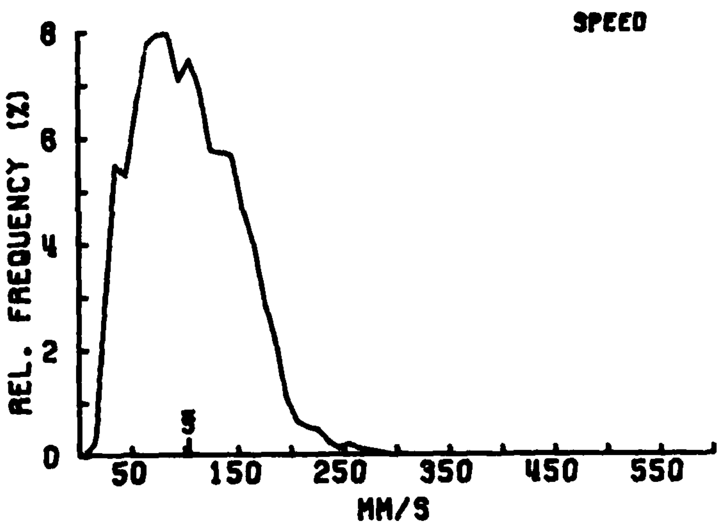


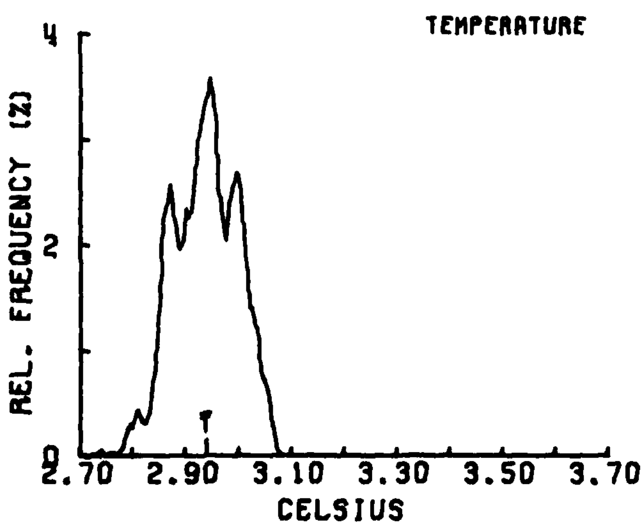


STATISTICS AND HISTOGRAMS RECORD 6202

```
*****************************************************************
** 6202C900      ** 33696 POINTS  FRCM 77-  V -16  TC 78-  V -02
INST. V-5110    DEPTH 2958 M.   UNITS = MM/S   , DEGREES CELSIUS
VARIABLE ------- EAST ------ NORTH ----- SPEED ---- TEMPERATURE
MEAN         =   -27.103       41.702      102.565        2.939
STD.ERR.     =      .244         .495         .257         .326E-3
VARIANCE     =  2012.082     8254.301     2220.288         .358E-2
KURTOSIS     =     3.271        2.009        2.806        2.467
SKEWNESS     =     -.794E-1     -.383         .468        -.131
MINIMUM      =  -205.077     -232.386       16.763        2.728
MAXIMUM      =   113.702      255.499      288.410        3.084
-----EAST & NORTH-------- * * * * * * * * * * * * * * * * * * *
COVARIANCE   = -2462.425  *
CORR. COEF. =      -.604  *
ORIENTATION =    160.864  *
MAJAX        =    95.440  *
MINAX        =    34.024  *
ELLIP        =      .643  *
*****************************************************************
```







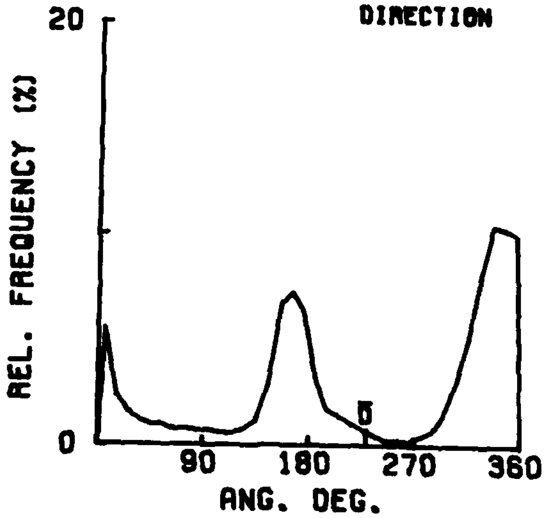
STATISTICS AND HISTOGRAMS RECORD 6203

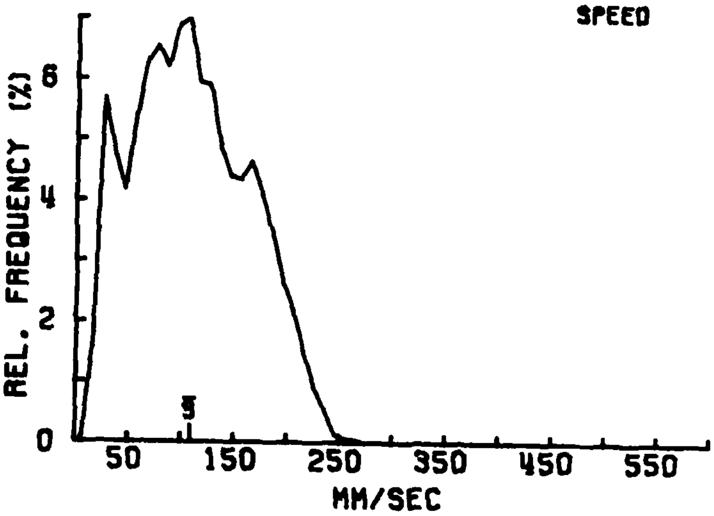
** 6203D900 ** 33698 POINTS FROM 77- V -16 TO 78- V -02

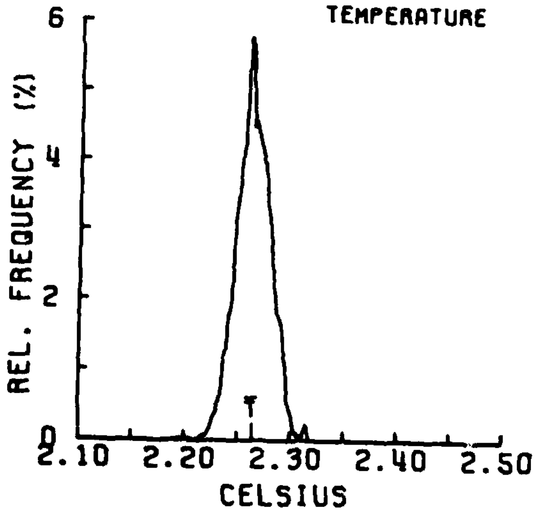
INST. V-0433 DEPTH 4987 M. UNITS = MM/SEC , DEGREES CELSIUS

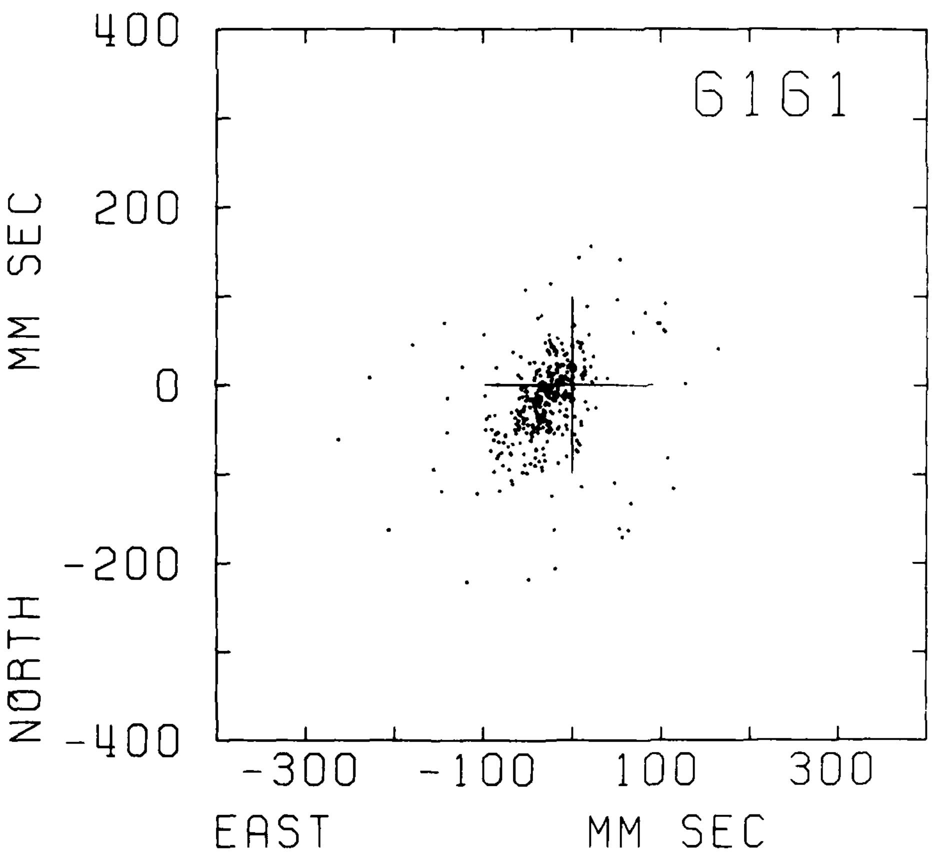
VARIABLE	EAST	NORTH	SPEED	TEMPERATURE
MEAN	-13.012	30.305	108.133	2.264
STD.ERR.	.252	.581	.294	.888E-4
VARIANCE	2143.344	11378.678	2917.498	.266E-3
KURTOSIS	2.739	1.962	2.230	3.461
SKEWNESS	-.191	-.214	.270	-.322E-1
MINIMUM	-170.281	-195.588	12.813	2.189
MAXIMUM	118.430	259.500	270.008	2.318

EAST & NORTH	
COVARIANCE	-3061.104
CORR. COEF.	-.620
ORIENTATION	162.229
MAJAX	110.911
MINAX	34.949
ELLIP	.685





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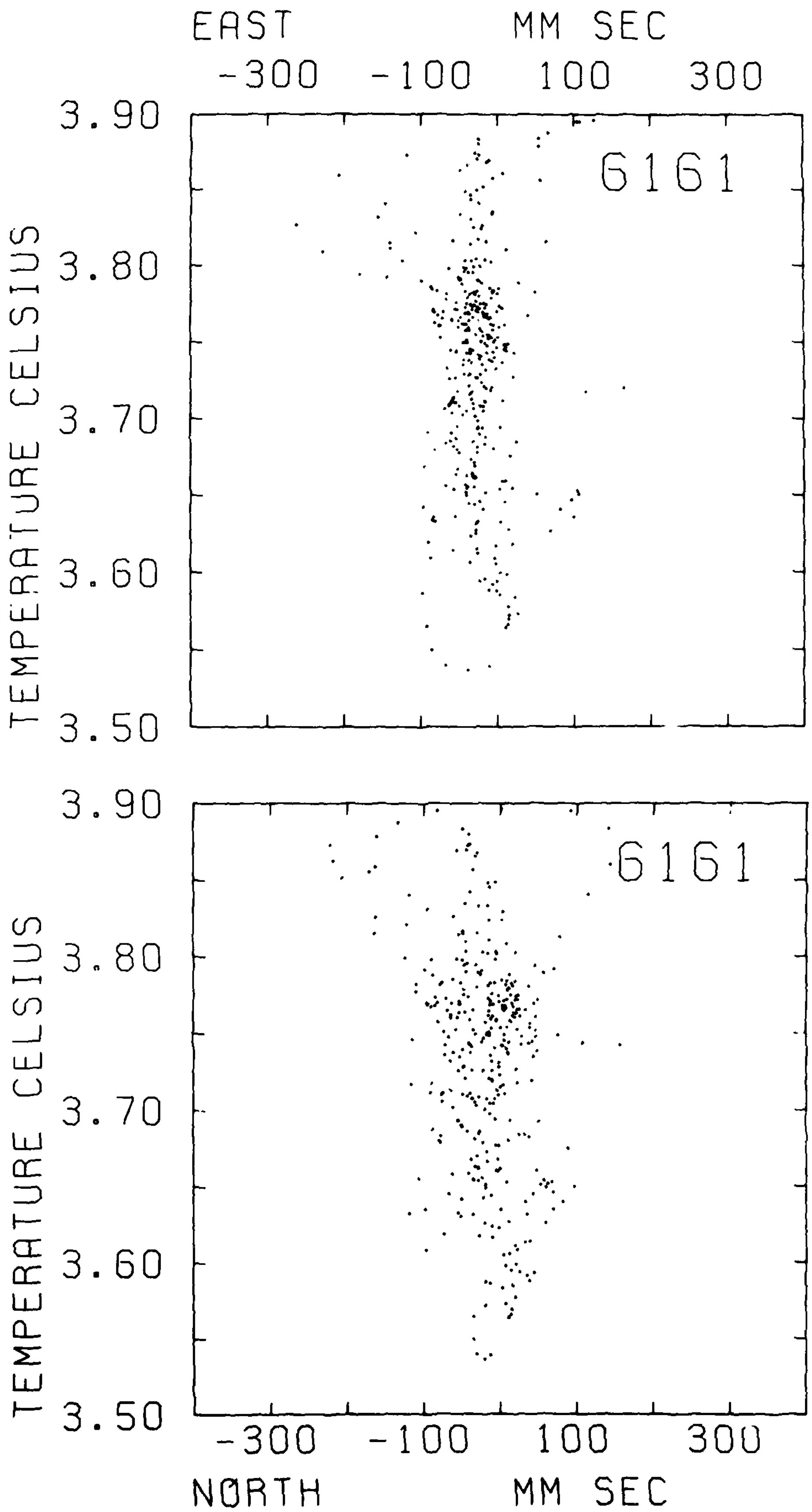
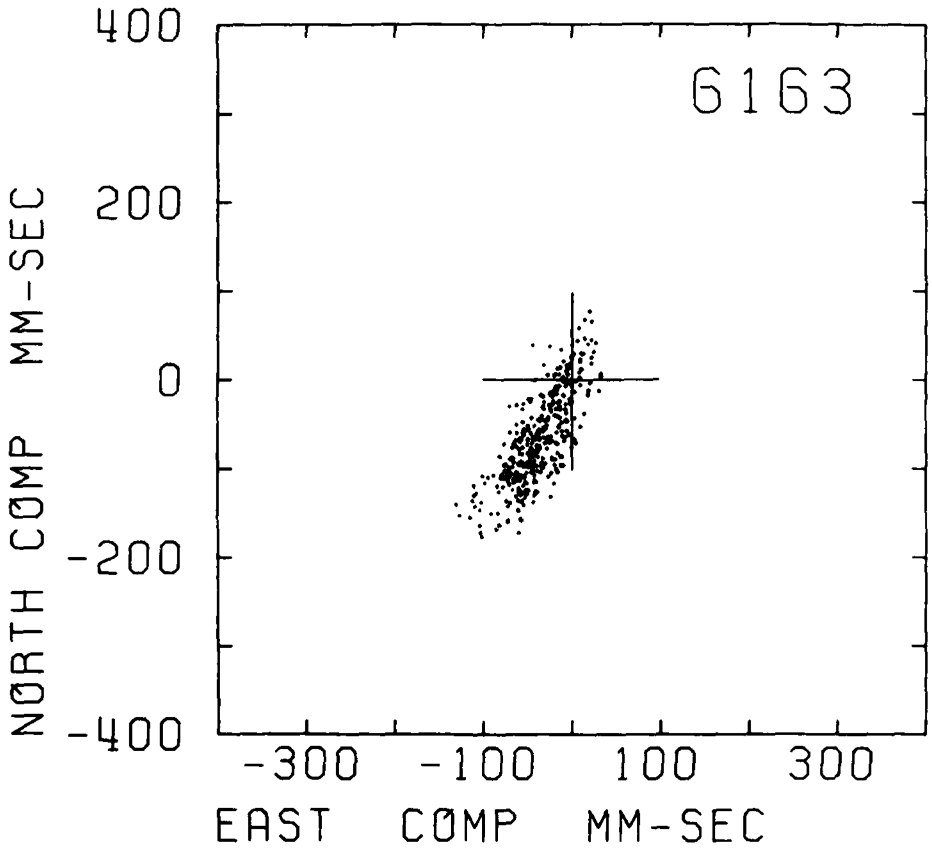
200
0
-200
-400
MM SEC
NØRTH
-300
-100
100
300
EAST
MM SEC


EAST
MM SEC
-300
-100
100
300
3.90
3.80
3.70
3.60
3.50
TEMPERATURE CELSIUS
6161
3.90
3.80
3.70
3.60
3.50
TEMPERATURE CELSIUS
6161
-300
-100
100
300
NORTH
MM SEC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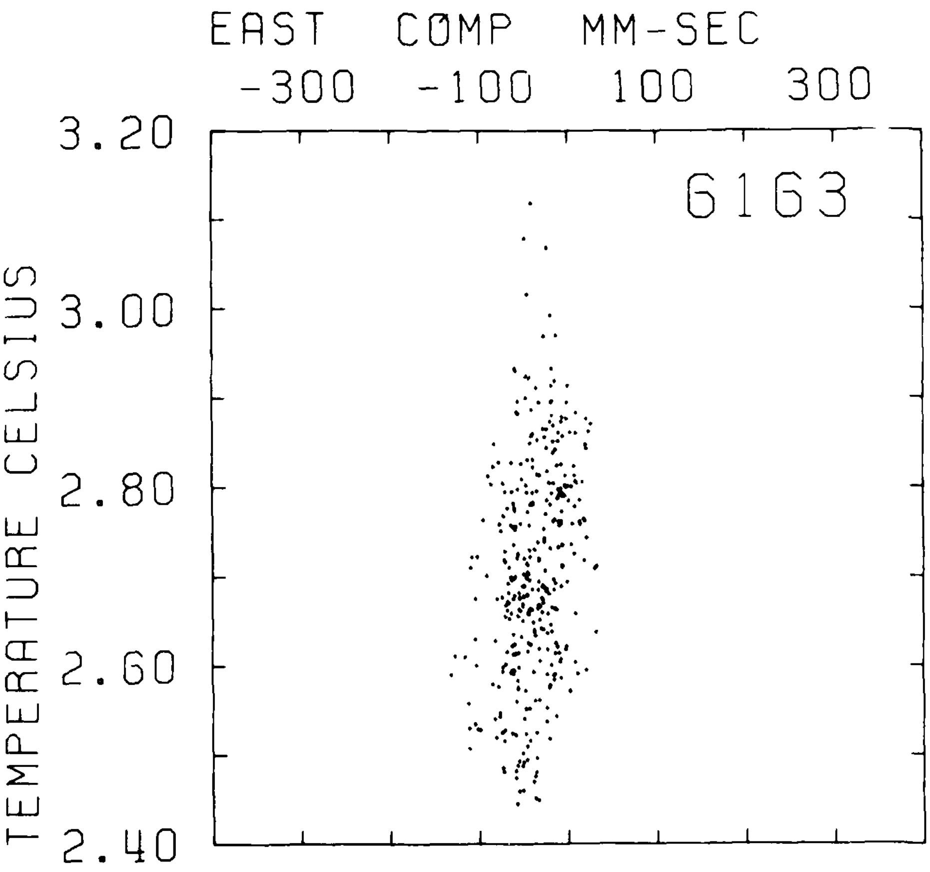
200
0
-200
-400
-300
-100
100
300
NØRTH CØMP MM-SEC
EAST CØMP MM-SEC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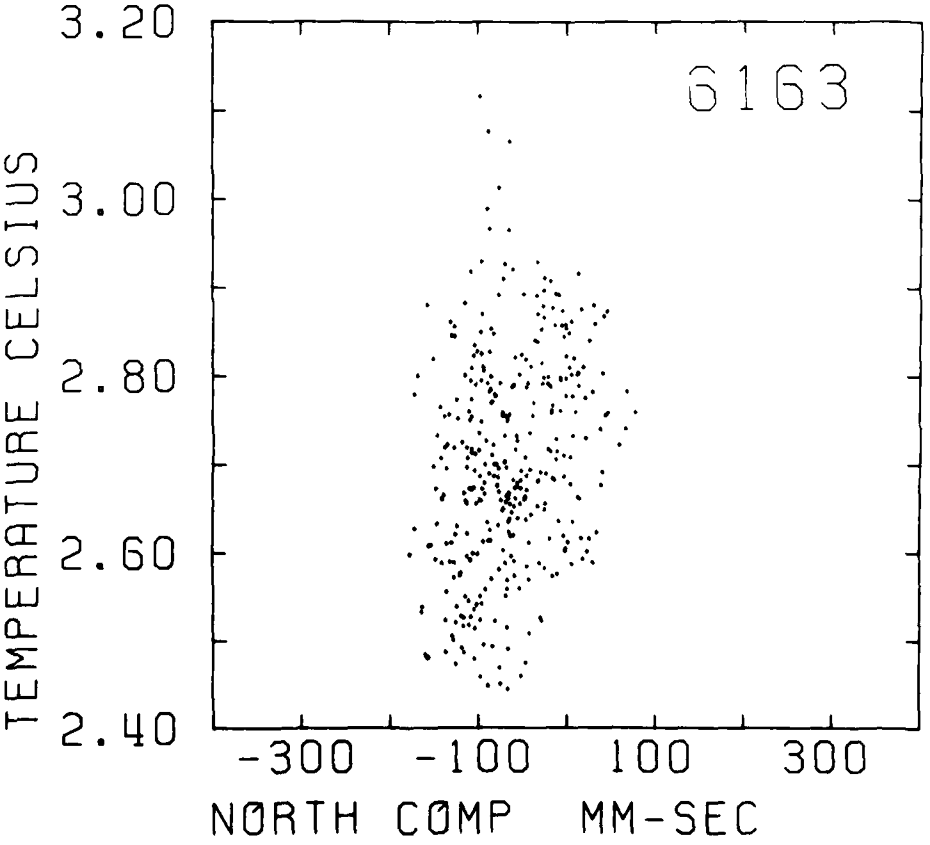
3.00
2.80
2.60
2.40
TEMPERATURE CELSIUS
6163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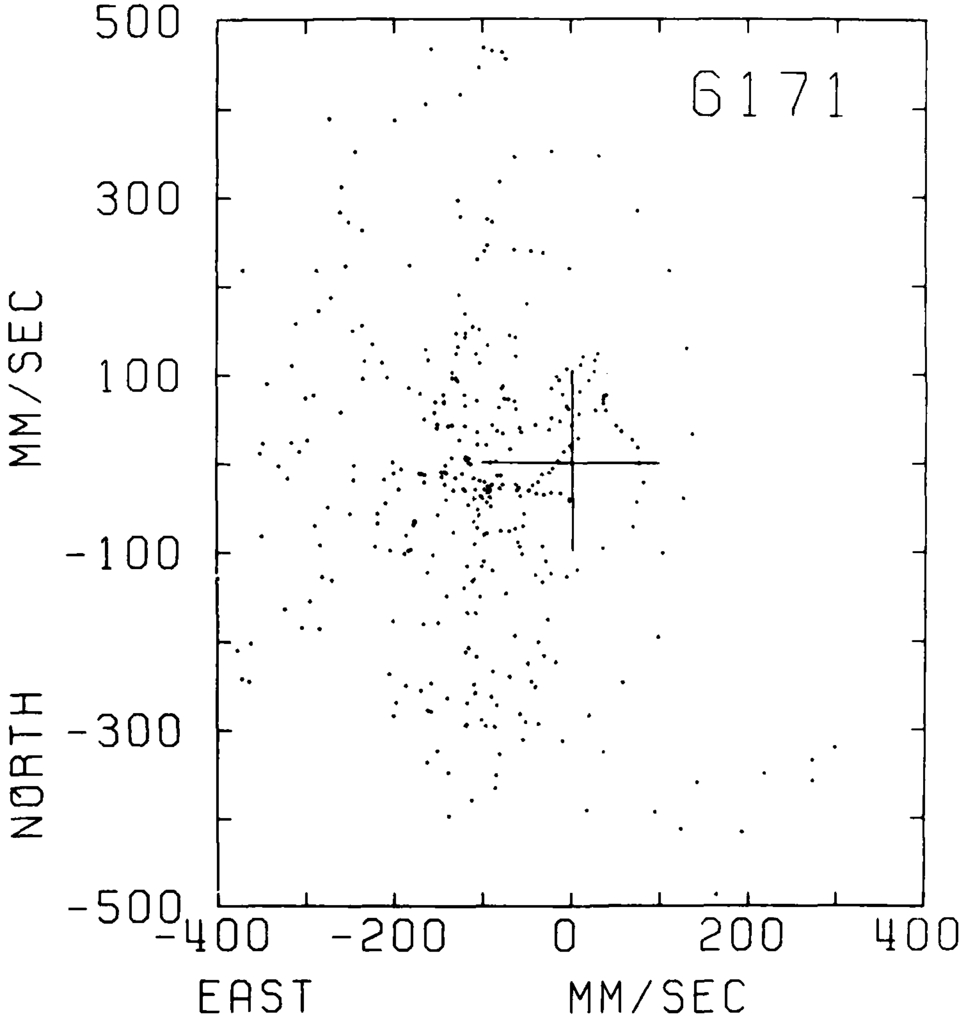
3.00
2.80
2.60
2.40
TEMPERATURE CELSIUS
6163
-300 -100 100 300
NORTH COMP MM-SEC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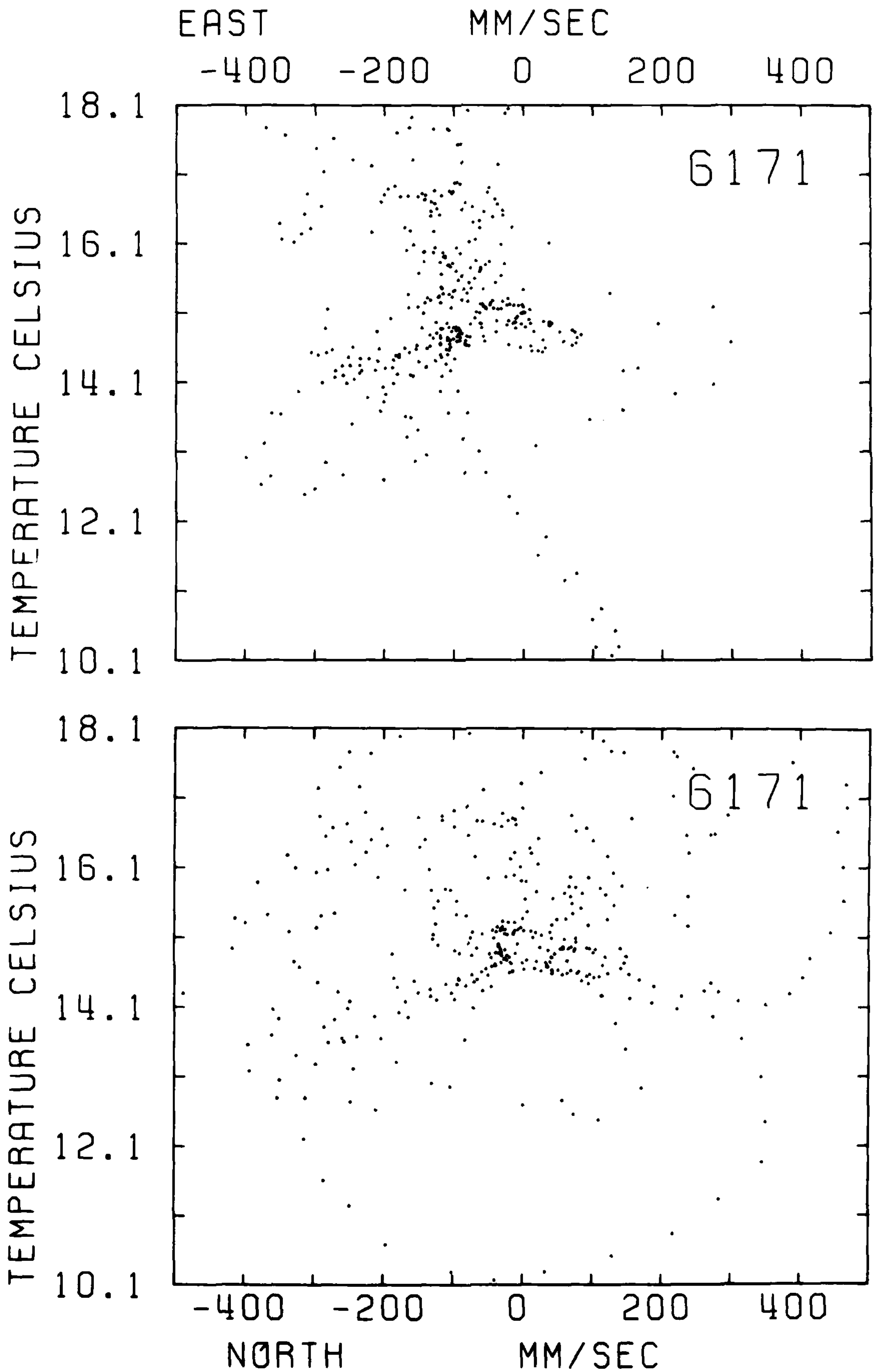
500
300
100
-100
-300
-500
-400
-200
0
200
400
NØRTH MM/SEC
EAST MM/SEC


EAST
MM/SEC
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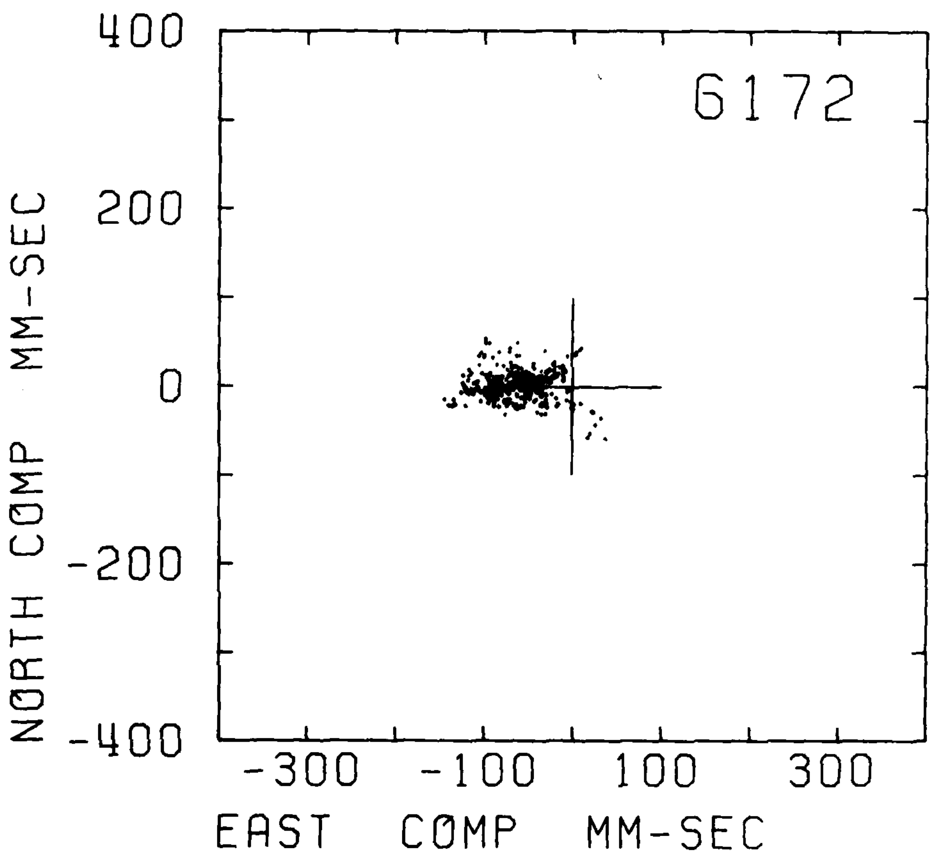
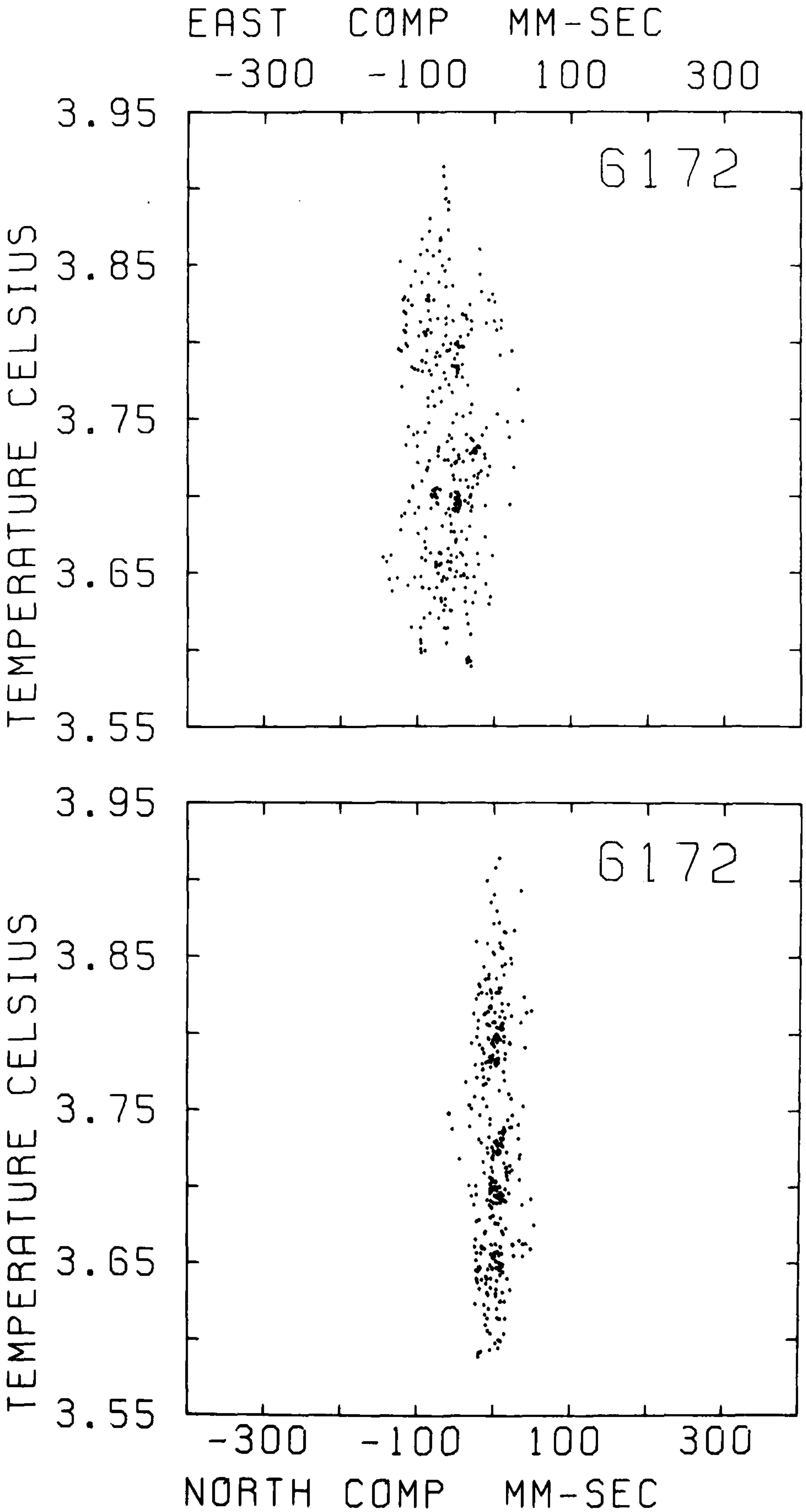
0
200
400
18.1
16.1
14.1
12.1
10.1
TEMPERATURE CELSIUS
6171
18.1
16.1
14.1
12.1
10.1
TEMPERATURE CELSIUS
6171
-400
-200
0
200
400
NORTH
MM/SEC


6172
400
200
0
-200
-400
-300
-100
100
300
NØRTH CØMP MM-SEC
EAST CØMP MM-SEC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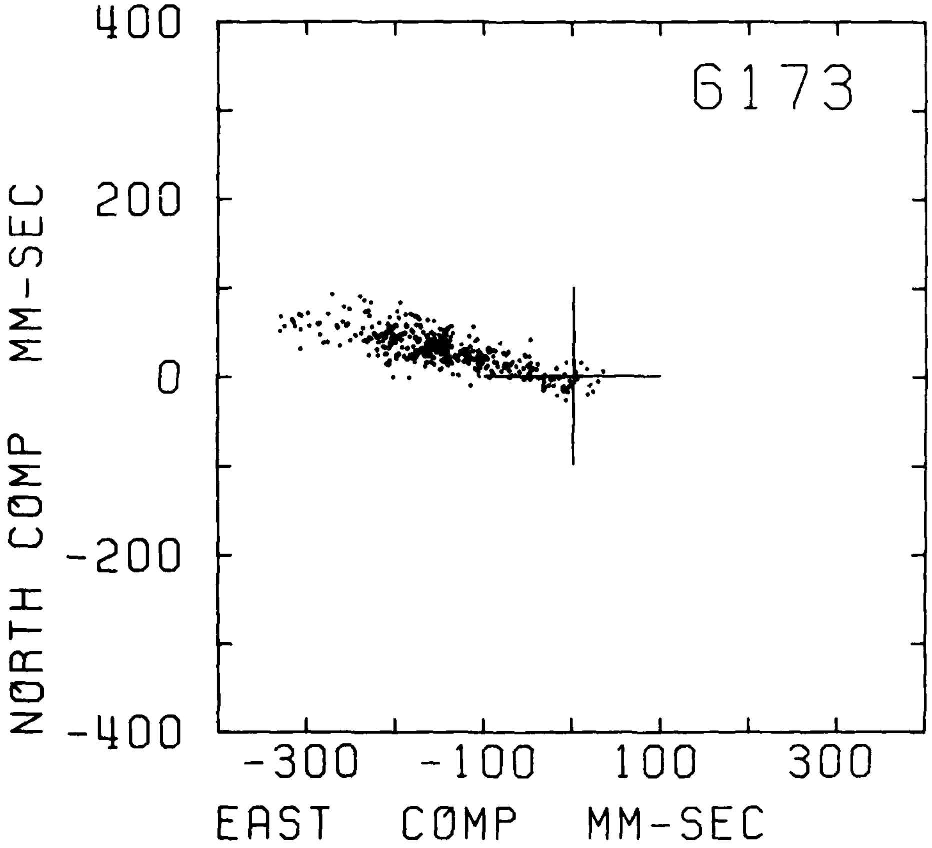
3.85
3.75
3.65
3.55
TEMPERATURE CELSIUS
6172
6172
-300 -100 100 300
NORTH COMP MM-SEC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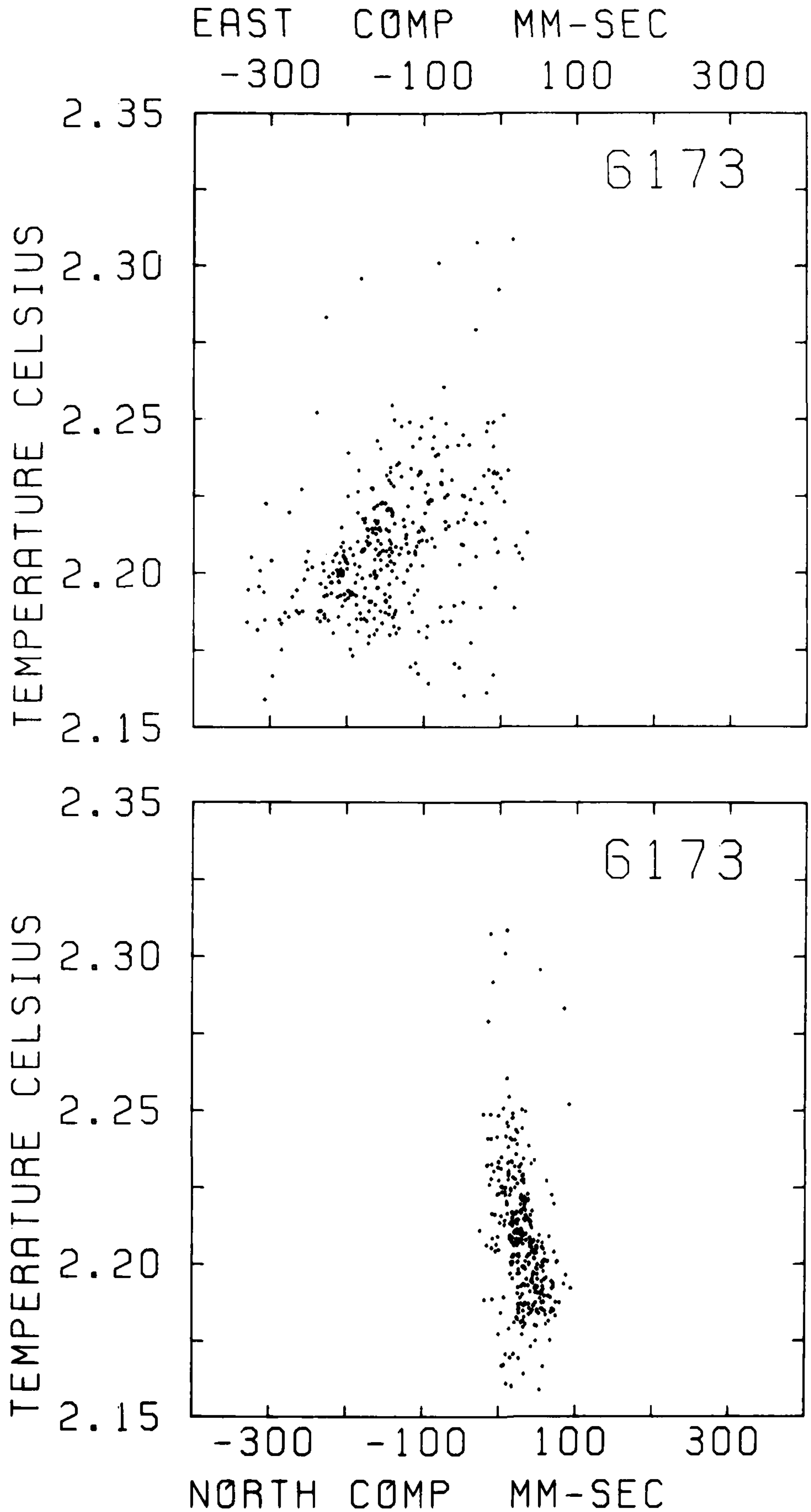
400
200
0
-200
-400
NORTH COMP MM-SEC
-300
-100
100
300
EAST COMP MM-SEC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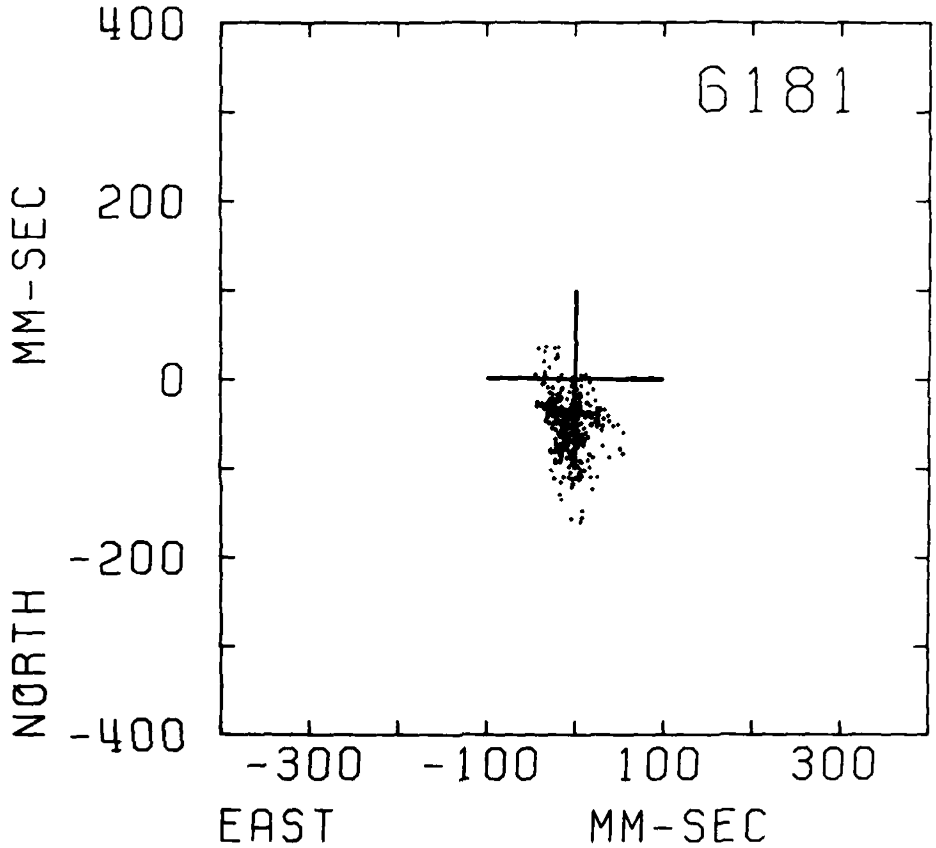
2.35
2.30
2.25
2.20
2.15
TEMPERATURE CELSIUS
6173
2.35
2.30
2.25
2.20
2.15
TEMPERATURE CELSIUS
6173
-300 -100 100 300
NORTH COMP MM-SEC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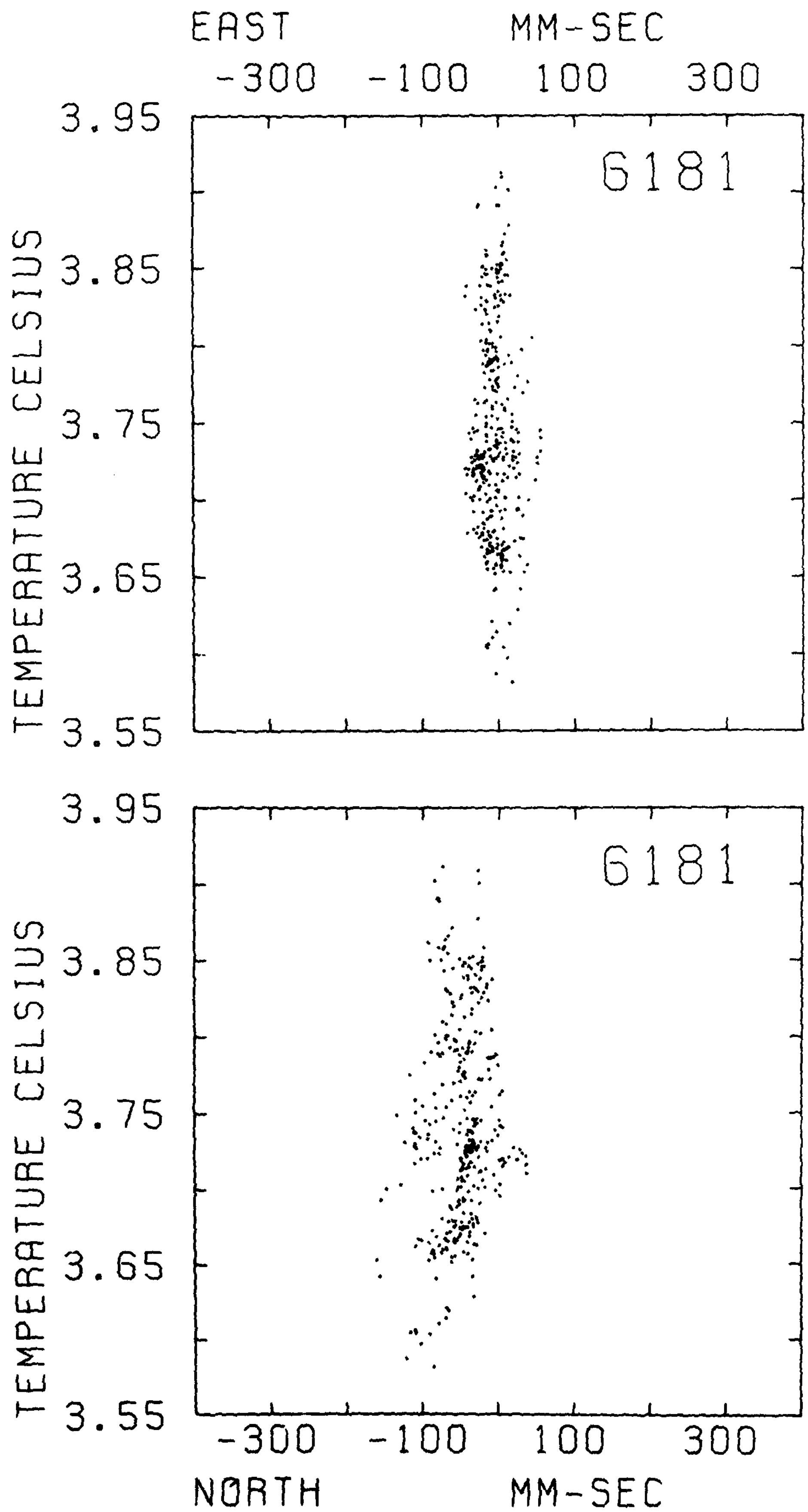
200
0
-200
-400
MM-SEC
NØRTH
-300
-100
100
300
EAST
MM-SEC


EAST MM-SEC
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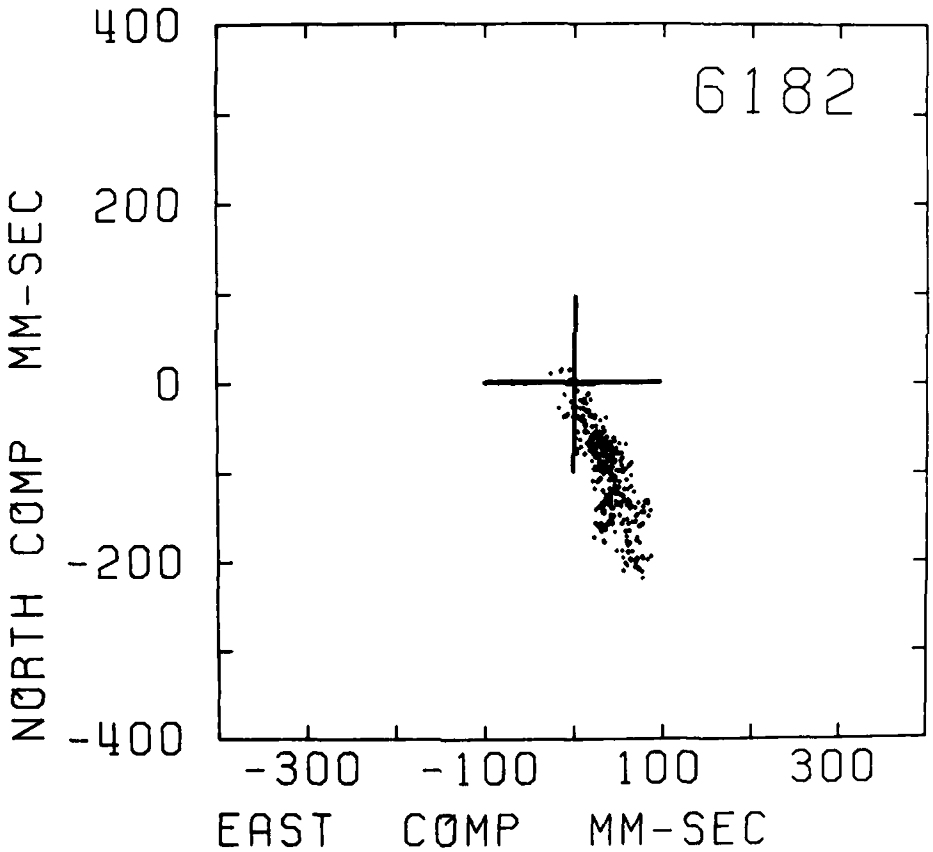
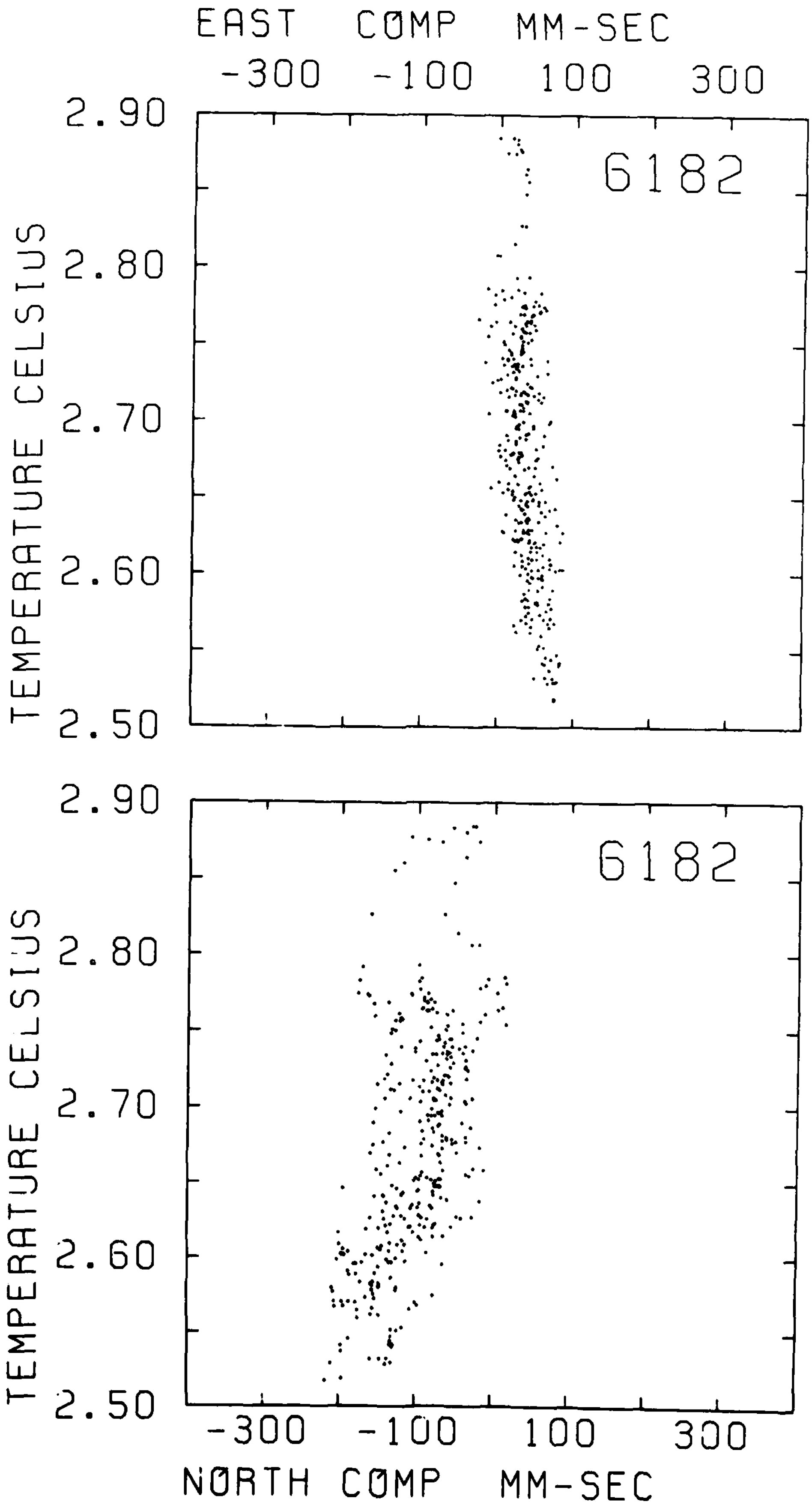
3.95
3.85
3.75
3.65
3.55
TEMPERATURE CELSIUS
6181
3.95
3.85
3.75
3.65
3.55
TEMPERATURE CELSIUS
6181
-300 -100 100 300
NORTH MM-SEC


6182
400
200
0
-200
-400
NØRTH CØMP MM-SEC
-300
-100
100
300
EAST CØMP MM-SEC


EAST COMP MM-SEC
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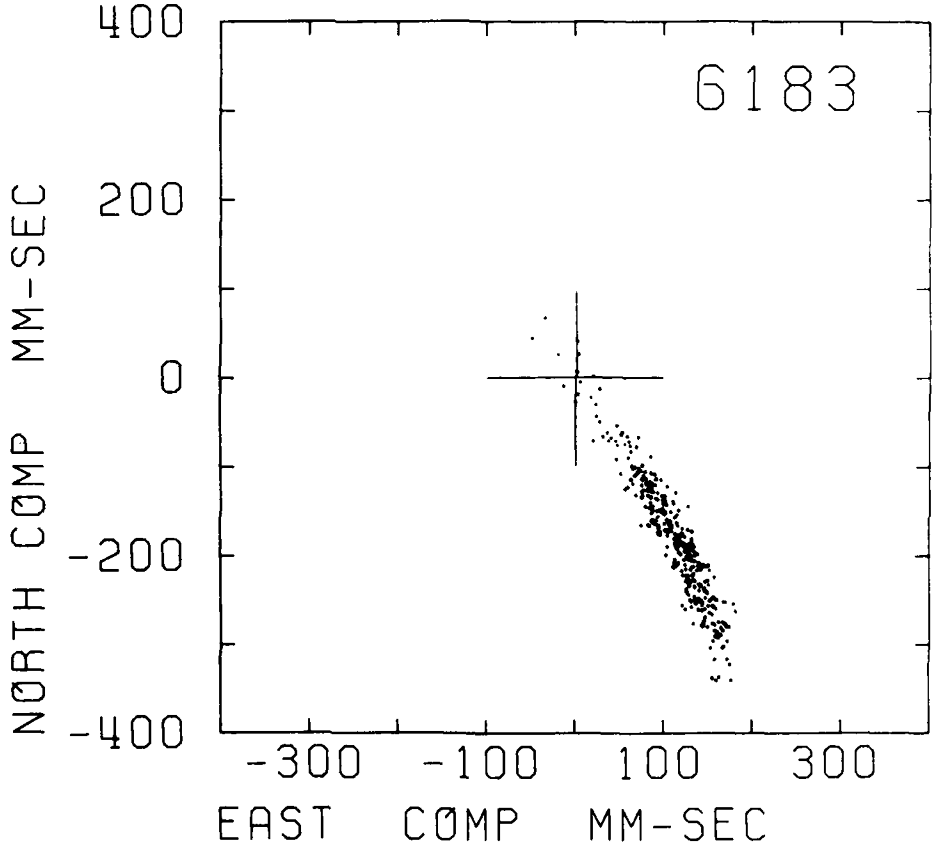
2.90
2.80
2.70
2.60
2.50
TEMPERATURE CELSIUS
6182
2.90
2.80
2.70
2.60
2.50
TEMPERATURE CELSIUS
6182
-300 -100 100 300
NORTH COMP MM-SEC


6183
400
200
0
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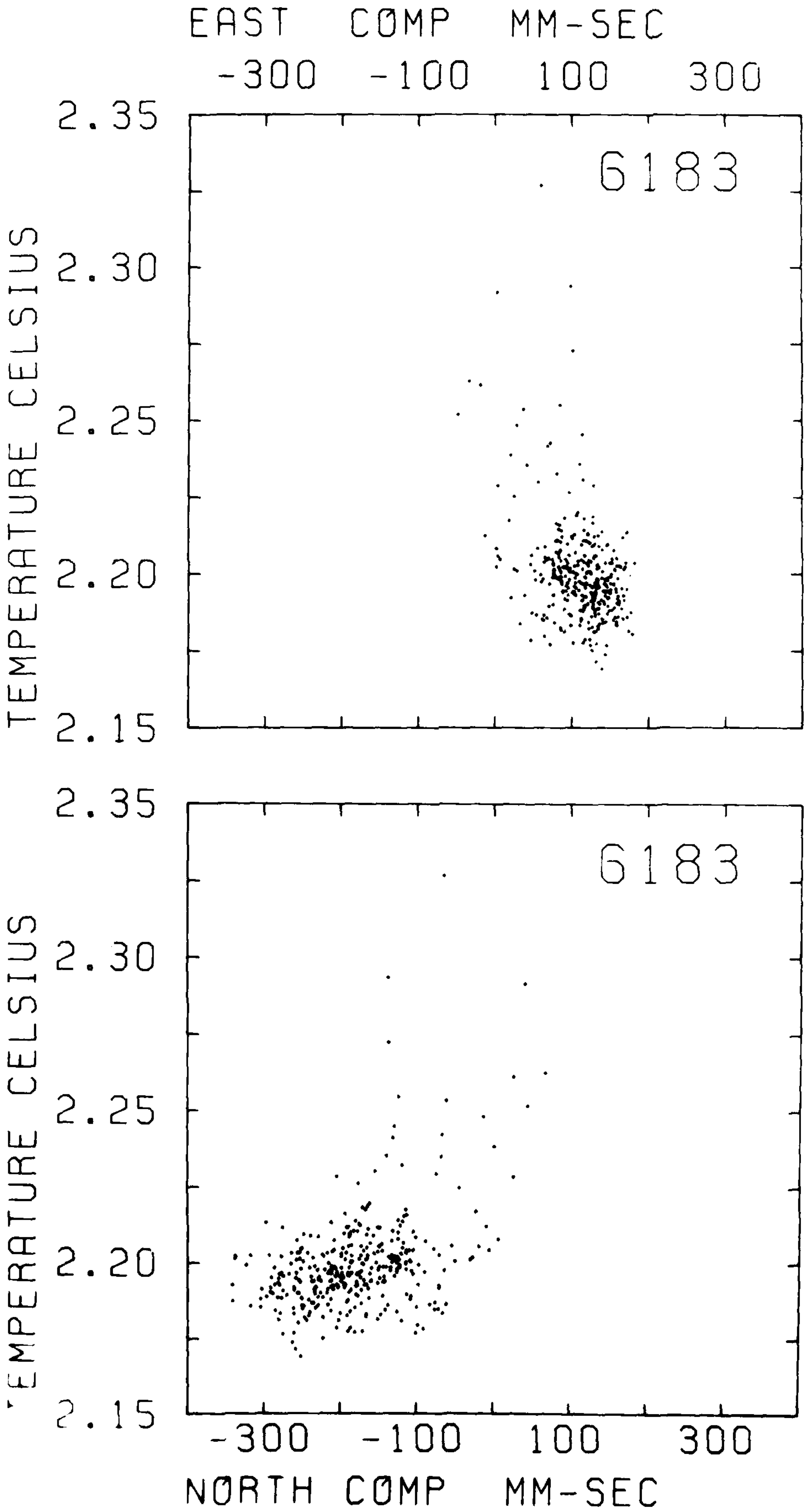
NØRTH CØMP MM-SEC
EAST CØMP MM-SEC



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-100
100
300
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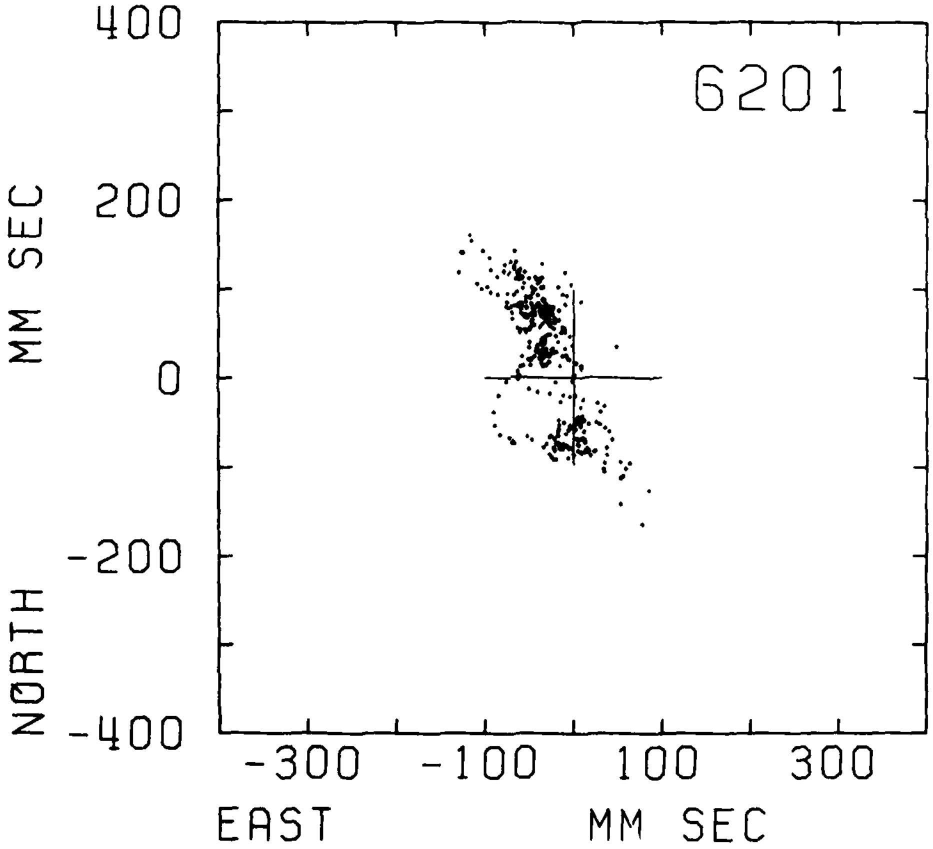
2.30
2.25
2.20
2.15
TEMPERATURE CELSIUS
6183
2.35
2.30
2.25
2.20
2.15
TEMPERATURE CELSIUS
6183
-300
-100
100
300
NORTH COMP MM-SEC



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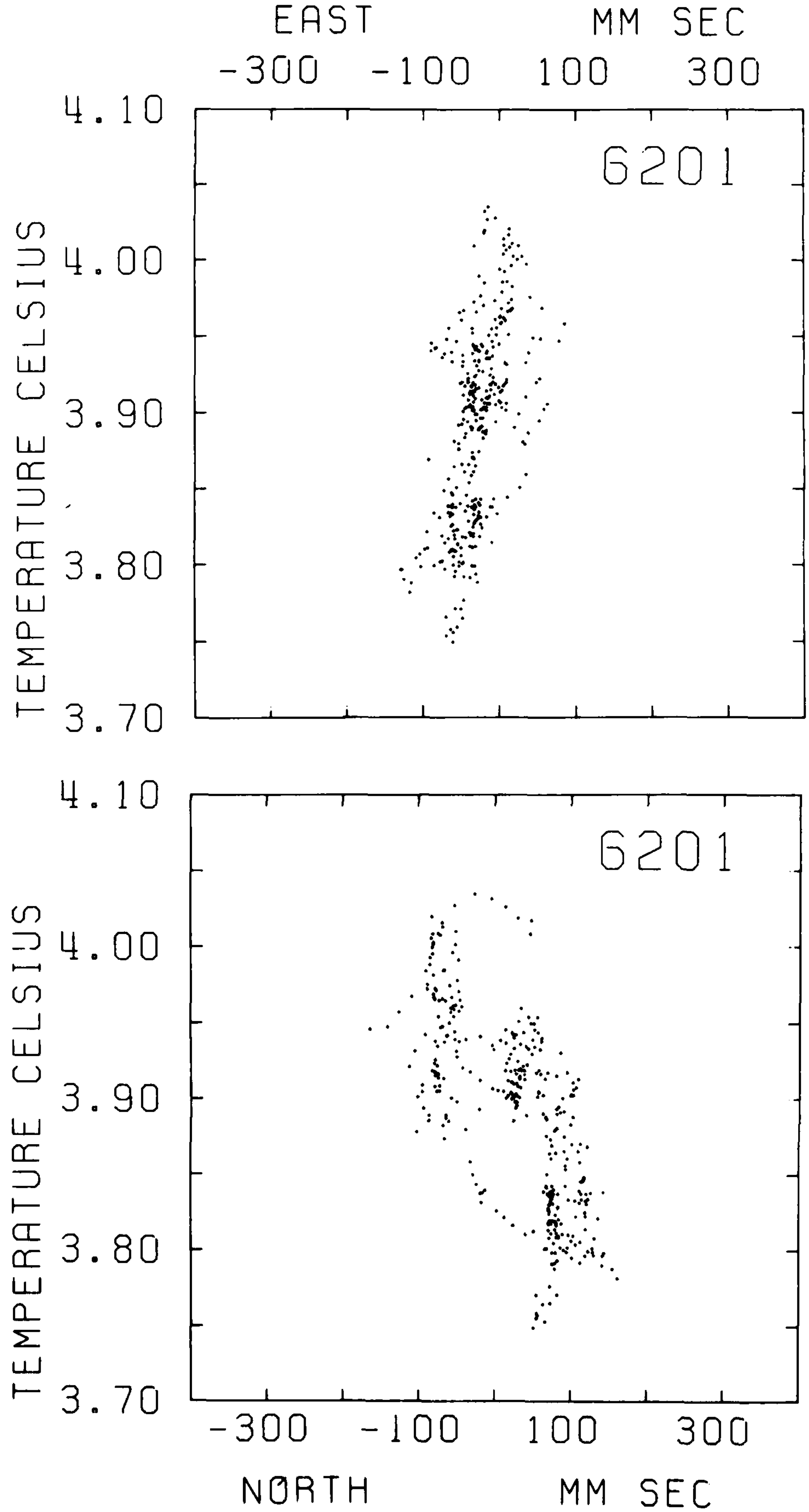
-200
-400
6201
MM SEC
NØRTH
-300
-100
100
300
EAST
MM SEC


EAST
MM SEC
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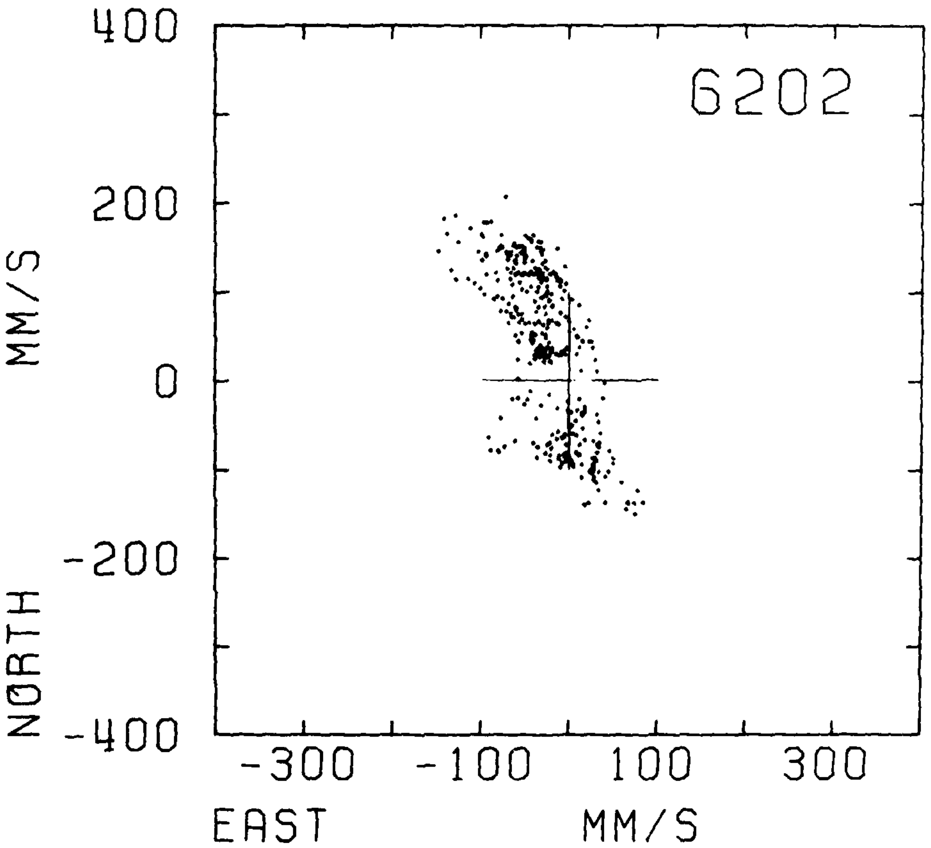
-100
100
300
4.10
4.00
3.90
3.80
3.70
6201
TEMPERATURE CELSIUS
4.10
4.00
3.90
3.80
3.70
6201
TEMPERATURE CELSIUS
-300
-100
100
300
NORTH
MM SEC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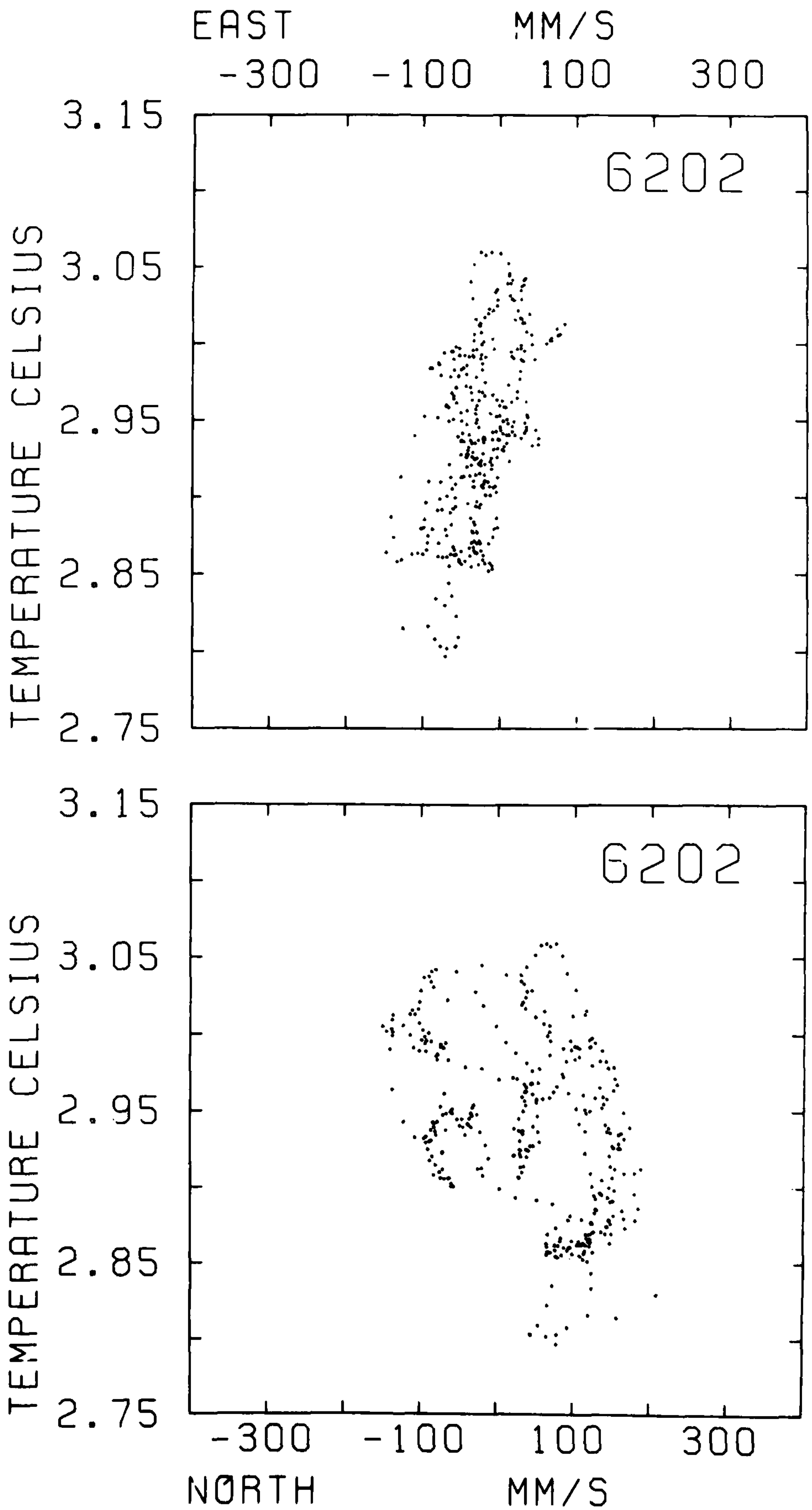
0
-200
-400
MM/S
NØRTH
-300
-100
100
300
EAST
MM/S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MM/S
-300
-100
100
300
3.15
3.05
2.95
2.85
2.75
TEMPERATURE CELSIUS
6202
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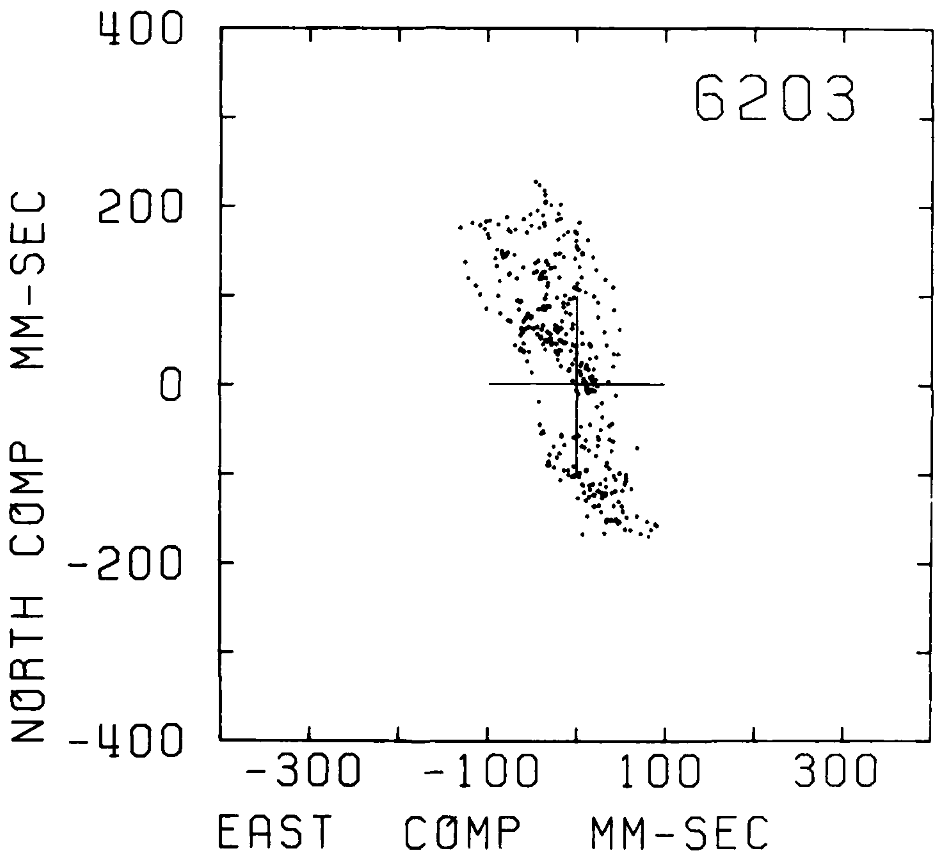
3.05
2.95
2.85
2.75
TEMPERATURE CELSIUS
6202
-300
-100
100
300
NØRTH
MM/S


6203
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EAST COMP MM-SEC
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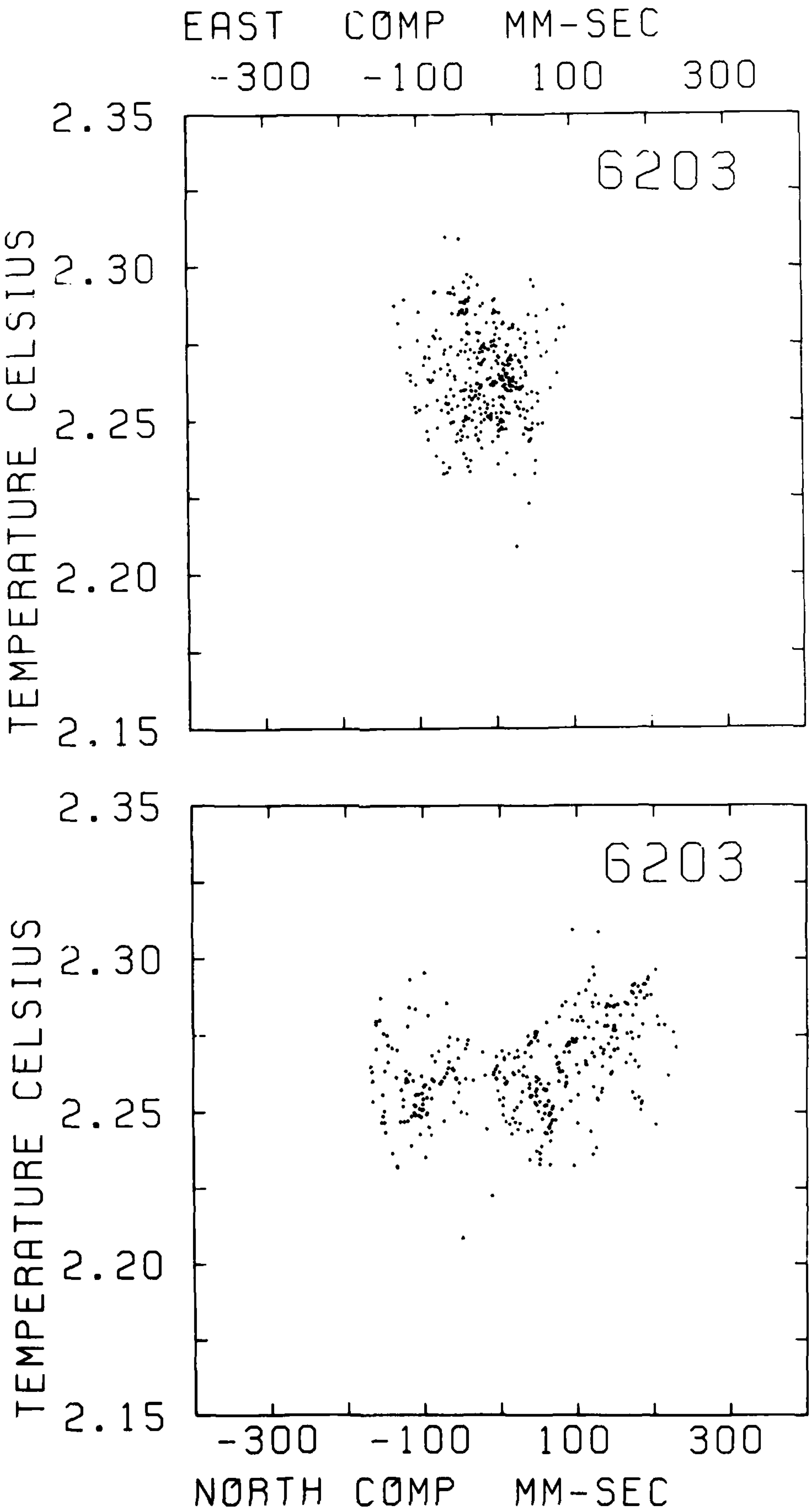
-300
-100
100
300


EAST COMP MM-SEC
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2.30
2.25
2.20
2.15
TEMPERATURE CELSIUS
6203
2.35
2.30
2.25
2.20
2.15
TEMPERATURE CELSIUS
6203
-300 -100 100 300
NORTH COMP MM-SEC

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2. Ocean Temperature
3. Blake-Bahama Outer Ridge

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